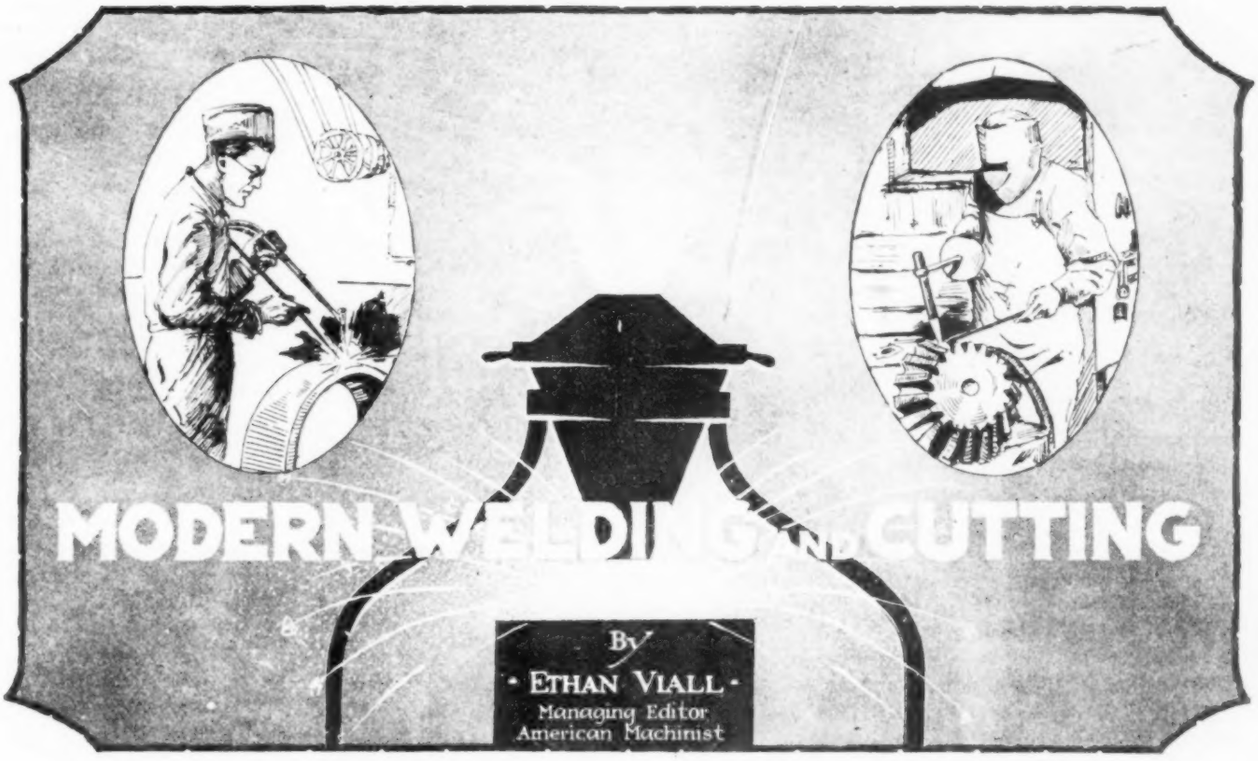
American Machinist



XVII—Making Allowance for Expansion and Contraction*

One of the big problems confronting all welders is that of allowing for expansion and contraction. The general principles will be better understood after a study of this article.

THROUGH his practice work, as already outlined, the beginner in welding has learned a little about the trouble that expansion and contraction may cause when proper allowance is not made. This was shown to some extent when he attempted to butt-weld two plates set close together. The remedy in that case was to allow for the contraction of the cooling metal and weld, by diverging the edges of the plates. From this example alone he can get a slight idea of the tremendous stresses often set up when, for instance, a broken spoke in a flywheel is welded without proper allowance being made for the amount of expansion in heating and contraction in cooling. These stresses *may* be so great as to quickly cause other fractures, or be of such a nature as to cause the subsequent destruction of the wheel. Different metals conduct heat with varying degrees of speed, that of copper being much more rapid than that of steel. On this account the welder must know something of the characteristics of the metal he is working on in order to obtain good results. However, except for the *amount* of expansion and contraction, the same *general* rules apply to all cases. It should be kept in mind at all times, that nothing can prevent this expansion or contraction of metals when heated or cooled, and that allowance in one way or another must always be made.

Where the ends of a broken bar are butt-welded together the parts are free to expand as they are heated, unless rigidly held. Suppose, however, that they are free to move, then when heated the broken ends will move toward each other, pushing the two parts of the bar in opposite directions when the heated ends touch. After the weld is complete, the cooling will cause the metal to contract, drawing the two parts of the bar closer together. In some cases the bar may be shorter than before, depending on the care and skill with which the weld was made. Owing to the fact that the parts of the bar are free to move no bad stresses are set up. Again suppose the bar happened to be part of a frame, as shown in Fig. 185. Then when heated at the break *A*, the ends could only move toward each other, in certain cases causing these ends to upset, or become thicker. After the weld was completed, the metal would start to contract, the tendency being to pull the cross ends in as shown at *B* and *C*. If the metal was ductile—that is, would stretch—it would probably actually bend in as suggested. Wrought iron or steel, for example, would probably do this. Cast iron would probably break. Aluminum would break or bend, according to the alloy used. In any case it would be a poor job, no matter how well the welding work itself was performed. The way to obtain a good job is to heat the frame at *D* and *E*, so that these side bars will expand as much as the middle one will while being welded. The contraction on cooling will then be the same on all three. Local heating like this is not always sufficient, and it is often necessary to heat the whole piece.

*For the author's forthcoming book "Welding and Cutting."

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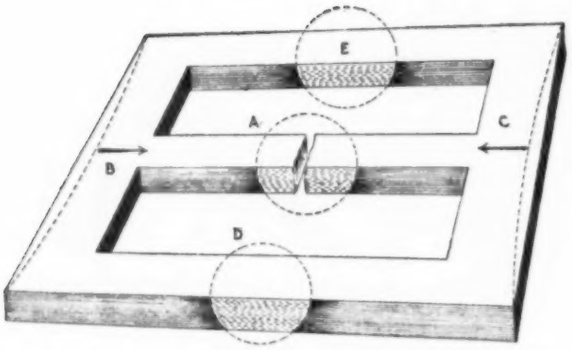


FIG. 185. BROKEN FRAME WITH PREHEATING ZONES INDICATED

Sometimes conditions are such that neither a part, nor the whole of a piece may be heated properly.

We may then use a jack to open the break in the middle bar a short distance, make the weld, and then slowly loosen the tension on the jack as the metal contracts. Or we may wrap wet cloths or wet asbestos or clay around the middle bar, close to the weld and keep cold water running on it while welding. This simply holds the expansion to a limited area and should be employed only when no other method is possible. Undoubtedly the better method in nearly all cases is the preheating of the article or a portion of it, though in each case proper judgment must be exercised.

The simplest way to preheat work is, as a rule, to build a temporary firebrick charcoal furnace, the form depending on the shape of the work. Where a piece like the frame just mentioned is to be heated all over, a furnace something like the one shown in Fig. 186 is very handy. Often an iron table and furnace like the one shown in Fig. 187 will serve for numerous repair jobs.

Where the nature of the work makes the use of charcoal unsuitable or impossible, a coal gas torch, kerosene torch, or even the welding flame itself, may be used. The last, however, is too expensive to use except where absolutely necessary. As a rule, a coal gas torch makes a very satisfactory means of preheating if it can be used. In using any preheating flame it is best to build up with firebrick or asbestos in such a way as to confine the heat where wanted. This also saves fuel. An Oxweld preheater using any grade of fuel, crude or kerosene oil, is shown in action in Figs. 188 and 189. This has two burners, and has to be pumped so as to have about 25 to 50 lb. pressure to get good results. The large size weighs 110 lb. One big advantage of a burner of this type is, that it may be carried anywhere and used. Where a shop has a compressed-air system and illuminating gas, the type of torch in Fig. 190 will prove exceedingly satisfactory. In case a shop does not have a compressed-air system, but has gas and electricity, the apparatus shown in Fig. 191 may prove useful. This is made by the Tyler Manufacturing Co., Boston. The motor driving the fan is of the universal type, operating on either alternating or direct current. One motor will supply air enough for four regular size burners.

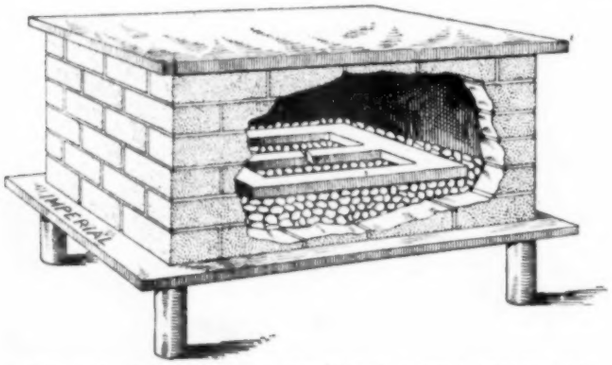


FIG. 186. PREHEATING FURNACE, USING CHARCOAL

Another torch is shown in Fig. 192. This also uses illuminating gas, the air being supplied by means of an electric driven fan. This device is made by the North American Manufacturing Co., Cleveland, Ohio. It is claimed that from 500 to 2500 deg. F. may be obtained with this torch.

For welding work of all kinds where proper alignment must be maintained, a table with a heavy cast-iron top is almost indispensable. Tables of this kind may be obtained from almost any of the supply firms. The Imperial Brass Manufacturing Co., Chicago, supplies a table with a firebrick top, as shown in Fig. 193. This kind of a table is very handy, as it enables the welder to construct firebrick furnaces of all kinds, and to so box in his work as to conserve all the heat possible. It also brings the work up to where he can work on it to the best advantage.

The cooling of steel or iron work after welding is often as important as the preheating. Some work must be annealed after it has cooled, by heating to a red heat and then slowly cooling again. Small parts may be buried in slacked lime, ashes or the like. Flat work may be laid in a sheet-iron box partly filled with lime and covered with sheet asbestos or more lime. In any case, the weld should be protected as much as possible from drafts. Where a firebrick furnace has been built up around some part, it may be closed in and the work allowed to cool as slowly as possible. The welder must use good judgment in all cases. It must not be thought that preheating is only necessary to take care of expansion and contraction, for while in small work this is often the only consideration, on large work it saves expense. By this it is meant that the use of charcoal, gas or other heating mediums is much cheaper than to try to bring the parts to be joined up to a welding heat with the welding flame alone.

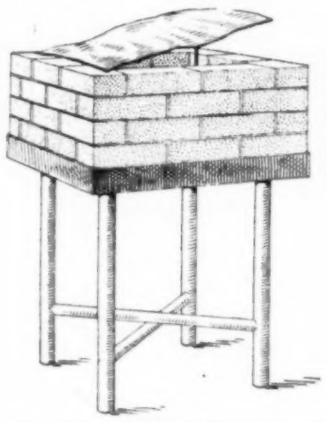


FIG. 187. PREHEATING FURNACE ON AN IRON TABLE

The way in which expansion and contraction will take effect, often requires considerable study. If the work can be heated all over, this is often the best way. As already mentioned, this is often not possible, so in order to assist the beginner, a number of examples will be given showing just where certain jobs should be preheated to get good results. A good thing to keep in mind as to where to preheat, is to imagine a wedge driven in at the break and note what places this action would put under strain.

Suppose a cast-iron grating to be broken in four places, as indicated at *A*, *B*, *C* and *D*, Fig. 194. It is best to weld break *A* first, preheating the corner as

shown, to a dark red. The weld is made while the section is at this heat, and when the weld is finished the piece is carefully covered over and allowed to cool. Break *B* is next welded. It will be noted that two ribs of the grating are heated in this case, because the break is internal. Next the weld *C* is made. This may be done in two ways. One way is to heat from the crack out to the corner, as indicated. The other, and safest way, is to heat the entire lower half of the casting. Break *D* is welded last. For this, either heat as indicated, or else heat the entire piece.

In Fig. 195 is shown how to preheat a pulley or flywheel, broken as indicated at *A* and *B*. Where the spokes are close together, the spokes on each side of the broken one should also be preheated, but where reasonably wide apart, the heating as shown by the shaded lines around *A* is sufficient. As usual the welding should be done while the parts are at a low red heat. The weld should be covered and allowed to cool slowly. Crack *B* may be welded after the first weld has cooled. When the crack in the rim is near a spoke, as shown, the heating should include the spoke and part of the

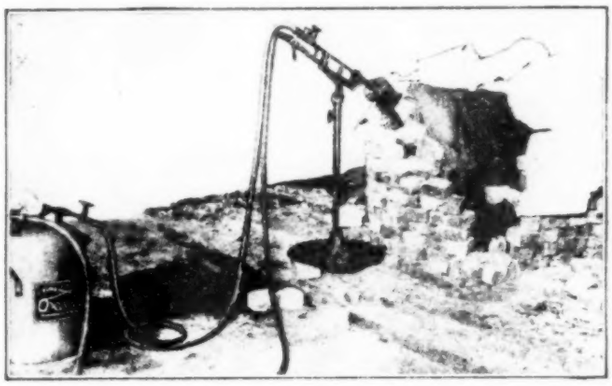


FIG. 188. CRUDE OIL OR KEROSENE PREHEATER IN ACTION

rim, but should be kept away from the hub. When the hub itself is broken, it is usually necessary to heat a large part, or all, of the wheel.

The next example is a block of two cylinders, broken as indicated in Fig. 196. The first break to be repaired is in the water jacket at *A*. The second break is on the flange at *B*, and the third is on the water jacket as shown at *C*. The fourth crack *D* is on the inside of the water jacket, necessitating the removal of part *E* by drilling in order to get at it.

To weld any of these cracks without preheating would break the casting from expansion when the flame was applied to it, and contraction when the weld cooled. The preheating in this case means the heating of the entire casting alike. To do this, build a furnace of firebrick, as shown at *F*. In order to give enough draft for the fire, the bottom bricks should be set about 1 in. apart. The cylinder block, with the cracks properly chipped and beveled, may then be placed on the first layer of brick and the walls built up around it. These walls should be so built as to allow about 6 in. between them and the cylinder. That is, there should be space enough allowed to turn the cylinder without knocking down the walls when ready to weld. About three or four shovelfuls of charcoal should be put around the cylinder and a little kerosene put on it and lighted. After the charcoal has become thoroughly lighted and the cylinder

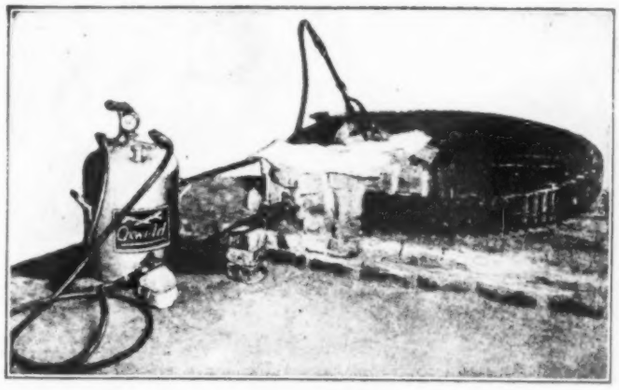


FIG. 189. USING TWO BURNERS TO PREHEAT A LARGE GEAR

slightly heated, more charcoal should be added until half the casting is covered. Then a piece of sheet asbestos should be put over the top, and a few holes punched in it for draft. Leave the cylinder alone until it reaches a dark red all over, then remove the asbestos and turn the cylinder so that the part to be welded first is uppermost. Then replace the asbestos and cut a hole in it so that the break can be reached with the torch and welding rod. Never take the cylinder out of the fire to weld. After welding, add more charcoal and heat the casting up until it is evenly heated all over, then allow it to cool slowly. Care must be taken not to let melted metal run

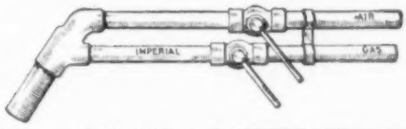


FIG. 190. A GAS AND AIR PREHEATING TORCH

down into the water jacket. Be sure to work out all dirt or scale, and do not leave any pinholes or blowholes. In order to prevent the bore of the cylinder from scaling, it should be coated with oil and a thin coating of graphite applied before the cylinder is placed in the furnace. After welding the graphite can be cleaned off with a piece of waste.

For crack *B*, the cylinder need not be heated so hot, as previously mentioned. The inner weld *C* is made the same as crack *A*. Crack *D*, being on the inside of

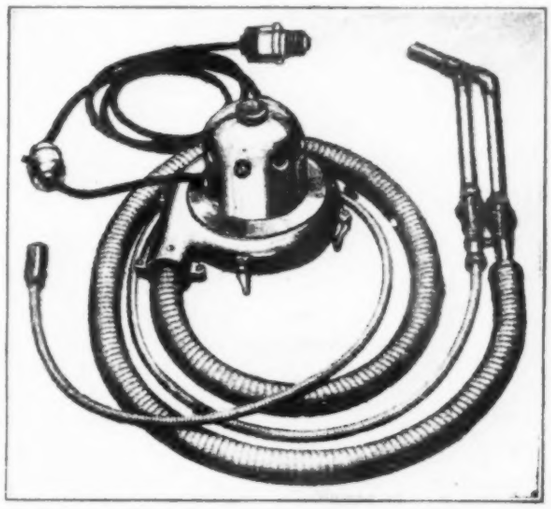


FIG. 191. PORTABLE ELECTRIC BLOWER-TYPE GAS-BURNING PREHEATER

the water jacket, is treated differently. A portion of the outer wall of the water jacket is removed by drilling, as previously mentioned. The inner weld is made, after which the removed portion is replaced and welded. In order to hold the piece in place while being welded a cast-iron rod may be welded to it to serve as a handle. After the weld is finished, this rod is cut off.

FIG. 192. PORTABLE PREHEATER MOUNTED ON A STAND

After the cylinder has been welded and cooled off, it should be tested to be sure that the weld is entirely tight. Where it is possible, this should be tested with water pressure. If it is not possible to do this, the water jacket should be filled with kerosene, because kerosene penetrates a crack or a pinhole faster than water.

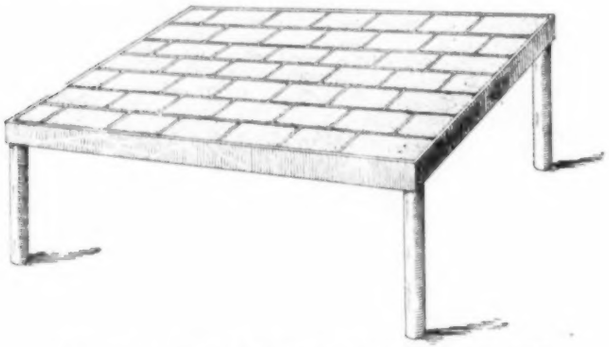


FIG. 193. IRON TABLE WITH FIREBRICK TOP

In case any leaks are found, the metal should be chipped out at that point, placed in the fire, and rewelded exactly as before.

The next job, illustrated in Fig. 197, is typical of a large class. Work of this kind is usually in cast-iron, though occasionally of steel, or semi-steel. The piece shown is a cast-iron shear arm broken where the section is about 6 or 8 in. thick and 16 in. across. In preparing a casting of this size, the break is beveled at 60 deg. for about two-thirds of the depth from one side. It is then lined up and a preheating firebrick furnace built around the break, allowing sufficient space for the charcoal around the work. Then heat to a bright red well back

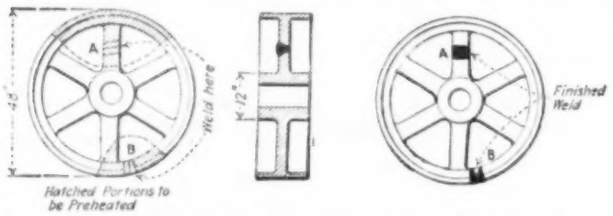


FIG. 195. BROKEN PULLEY, WITH PREHEATING ZONES SHOWN

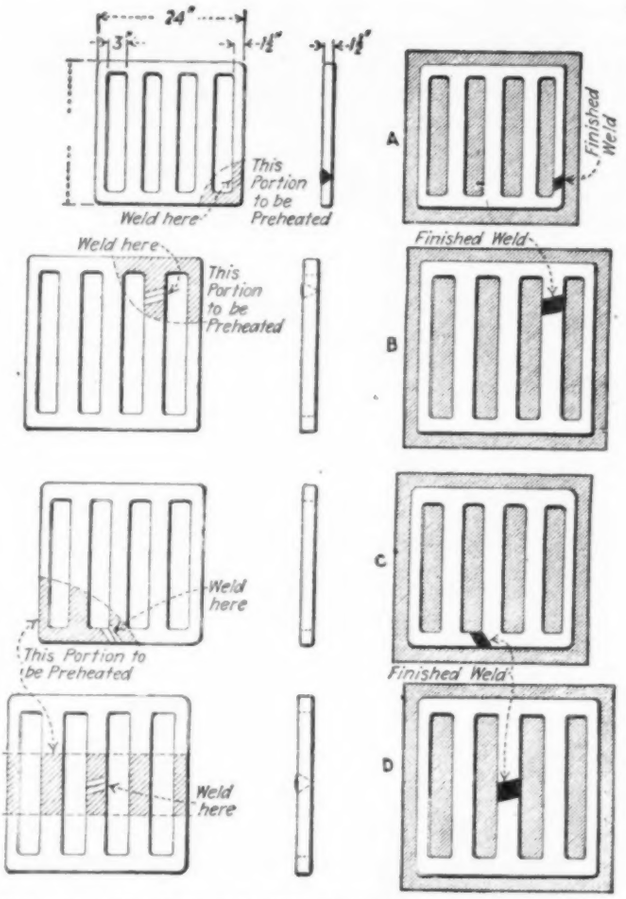


FIG. 194. GRATING BROKEN IN VARIOUS PLACES, WITH PREHEATING ZONES INDICATED

from the break. Two welders should work on a job of this kind, each welding about half an hour or less, at a time. A large welding head, a long-handled torch and ½-in. welding rod are used. Two rods should be used, welded end to end. There should be plenty of rods and plenty of flux. There should also be a good supply of asbestos sheet and a bucket of water. The sheet is to keep in the heat and to protect the welders, and the water is to cool the torches. After the weld is completed on this side, and while the metal is still hot, the casting is turned up on edge so that the weld is in a vertical position. The crack on the opposite side from the weld is then melted

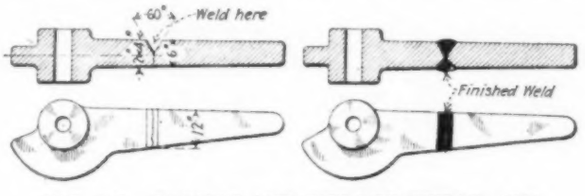


FIG. 197. BROKEN AND WELDED SHEAR ARM

out with the torch. This should be done by starting at the top corner and flowing the metal out. As it flows down and sticks to the casting, it should be pushed off with the rod. The crack is melted out so that a "V" of about 60 deg. is formed. When this is done, the casting is turned over with this channel up. These movements will naturally destroy the firebrick furnace, which has to be rebuilt again, the casting heated up as before, and the weld made. In a job of this kind it is necessary to reinforce the weld on both sides. This reinforcing should

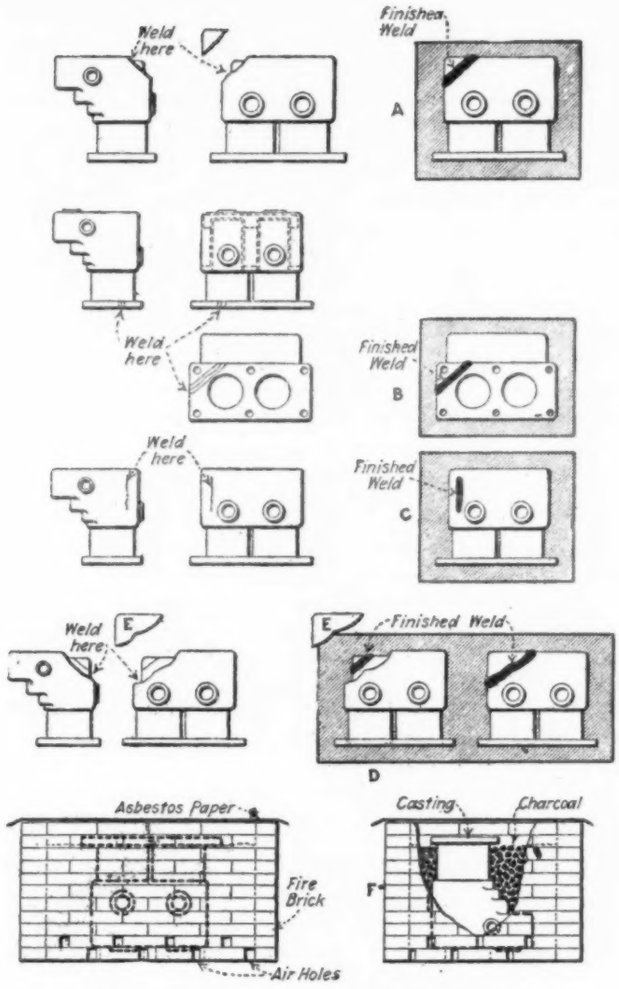


FIG. 196. BROKEN MOTOR-CYLINDER BLOCK AND PREHEATING FURNACE

be about ½ in. high. After the welding is all done, the piece is heated up to an even red heat all around the weld and allowed to cool very slowly.

In welding in or building up gear teeth, as shown in Fig. 198, it is not always necessary to preheat. If the gear is a light one, say about 3 in. wide and with a rim depth of not over 1 in., the job can usually be done without preheating. Where necessary to preheat, it can be done in the same way as outlined for a flywheel. In doing a job of this kind the greatest care must be taken to start properly. The work should be done so as to do away with as much machining as possible. Sometimes the tooth may be built up about as shown at *A* and finished by filing or otherwise. At other times it will be necessary to weld in on teeth each side of the one to be replaced, as shown at *B*. Again it may be possible to use carbon blocks and fill in as shown at *C*. In using blocks of this kind, care must be taken that there is ample room at the bottom for the root of the tooth being replaced.

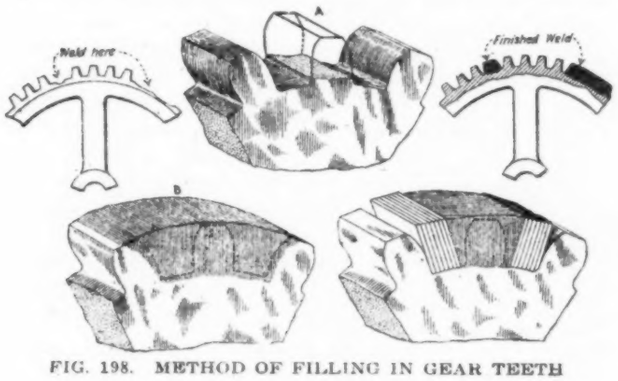


FIG. 198. METHOD OF FILLING IN GEAR TEETH

Factors to Be Considered in the Selection of Materials

BY DEAN HARVEY

In selecting a material for a new application there are several factors which should be given careful consideration. These factors may be divided into four classes as follows: (1) serviceability; (2) uniformity; (3) availability; (4) price.

Their relative importance may vary with the application, but in many cases will be in the order mentioned.

(1) Serviceability—The first requirement is that the material has the essential characteristics for the purpose for which it is to be used, with ample factor of safety to allow for variations in commercial manufacture. This is so clearly evident that it should not be necessary to emphasize it, but cases are occurring every day where material of good quality is proving unsatisfactory because it is used under conditions for which it is not adapted.

For example: A cold-drawn steel, known as automatic screw stock, is made quite accurate in diameter and with chemical composition especially adapted for automatic screw machine work. This application requires a rather brittle steel in order to allow it to be free cutting at high speed and to give a smooth finish when machined. On account of its accurate dimensions, its superior finish, and because it is readily available, this material is often used in applications where a tough steel is required to withstand shock. As a result the steel breaks in service, not because it is defective, but because it is not suitable for that application.

The material should be adequate for the purpose, but without unnecessary refinements to add to the cost. This is well expressed by the old saying "Good enough is best." For instance, it would be an extravagance to use expensive malleable-iron castings where ordinary cast iron would do as well.

It is sometimes found economical to use the higher grade of two materials, thus allowing a smaller amount to be used, due to its superior qualities. Sheet-steel parts, when manufactured in sufficiently large quantities to absorb the cost of tools, have often been used to replace cast-iron parts, thus providing a lighter, stronger construction at lower cost.

(2) Uniformity—Uniform quality is very desirable as it enables the designer to utilize the material to the best advantage. When there is excessive variation in quality it is necessary to use a larger factor of safety and the weight of the apparatus will be increased, with a consequent increase in cost.

In order to furnish material of uniform quality it is usually necessary for the manufacturer to produce it regularly and on a commercial scale. He can then develop the best method of manufacture, systematize it, and train his employees so that the same process will always be followed and consistent results obtained. Practice makes perfect and new methods cannot be ex-

pected to produce the best results at once. Standard commercial grades are to be preferred and used whenever possible. Special materials are subject to considerable variation, and duplicate orders may not correspond to the original material.

The degree of uniformity of a material also depends to a large extent upon the degree of refinement during manufacture. For instance, crude oil has a much wider range of variation in its properties than the various oils refined from it.

It is sometimes necessary to use a higher grade of material than is apparently required, in order to obtain uniformity, whereas the lower grade would be satisfactory except for the variation in quality.

In order to insure uniformity, many users prepare specifications giving the desired characteristics with the permissible variations, and inspect each shipment, checking it to the specification. Inspection may be made either at the place of manufacture before shipment, or at the works of the purchaser.

Inspection and testing may sometimes be done most efficiently and economically by one of the companies which make a business of inspection work and maintain a corps of inspectors in various districts. This plan has the advantage of inspection at the place of manufacture by inspectors who are familiar with the materials in question because they are constantly inspecting them. The inspectors of the purchaser in many cases are unable to become thoroughly familiar with all the materials which they inspect, on account of the large variety of materials purchased.

There are also instances where the purchaser orders the same material from several suppliers and cannot take care of the inspection. For example, a company purchasing large quantities of axle steel placed orders with five steel companies. The inspection department was not able to inspect the steel at five mills at the same time. Arrangements were made for the steel to be inspected by one of the inspection companies, and excellent results were obtained. A report on each heat of steel, including chemical analysis and physical tests, was made by the inspection company to the purchaser.

The American Society for Testing Materials has done excellent work in preparing specifications for standard materials, including steels, non-ferrous metals and alloys, cements, etc. Their specifications have been prepared by committees in which were represented both the principal producers and users of the materials in question, and consequently are widely accepted as standard.

(3) Availability—The question of the availability of materials is of more importance than is generally recognized. Materials are frequently chosen without considering whether they can be obtained in the necessary quantities within the time specified. This has often resulted in serious delays in production, when other materials, which would have been equally satisfactory, could readily have been obtained if originally specified.

In addition to the use of commercial grades of materials, as previously suggested, standard sizes which are carried in stock or are constantly being manufactured by the supplier should be selected whenever possible. This enables prompt shipments to be made, and permits the storekeeper to reduce the amount of stock carried, as it can quickly be replenished.

Special grades, particularly when ordered in small quantities, will usually require a much longer time to obtain than standard grades.

In order to insure an available supply, it is desirable to have several suppliers on the approved list, whose product is interchangeable. With only one supplier, a fire or other interference with his business may cause serious delay and loss to the users of his products.

(4) Price—Last but not least, the price of the material must be given consideration. In general, the best prices can be obtained when a standard, commercial product is ordered. Manufacturers can produce it at a minimum cost, for the manufacture has been thoroughly developed and systematized. Being made by several suppliers, competition tends to keep the price down to a reasonable figure.

Even though for some reason a standard material cannot be used there should be at least two sources of supply, both from the standpoint of availability and price.

For a number of years a certain material was purchased from one company, as its product was considered to be superior to that of any other manufacturer. After the price had twice been increased, other manufacturers were allowed to submit samples and prices, and an equivalent material from another supplier was found. As a result, a reduction in price of more than 30 per cent. was obtained from the original supplier, for he realized that he had competition.

In connection with a new design a special wooden handwheel was made in small quantities at a cost of five dollars each. Upon further investigation it was found that the Ford automobile steering wheel without the spider was entirely satisfactory and could be obtained for 75 cents.

In conclusion: When selecting materials, the four elements—serviceability for the application, uniformity in quality within commercial limits, availability in ample quantity within the time specified, and price low enough to insure reasonable cost for the finished apparatus—should be given due consideration in order to obtain the highest efficiency in commercial manufacture.

A Novel Rope Drive Take-up

By E. A. Dixie

I recently encountered something entirely new to me in the way of a take-up for a manila rope drive. It is a well-known fact that new manila ropes stretch excessively and some sort of take-up is usually incorporated in the drive to take care of the stretch. Owing to excessive stretch a new rope had become so long that the take-up, a weighted affair, was resting on the ground and the rope was slipping badly on the pulleys. To shut down, cut a piece out of the rope and make another splice would have taken about two hours and this time could not be spared. The engineer in charge had noticed that the ropes always took up some of the stretch during the humid weather. He therefore took an empty can, punched a small hole in the bottom, filled it with water and hung it so that the water could drip on the rope. In less than half a minute after the first drop had fallen on the rope the take-up weight was lifted from the floor by the contracting rope. When the rope had contracted to the limit of the take-up the water was shut off. By alternately wetting the rope it ran till the rush was over and the new splice could be made. Some may think that the water would tend to rot the rope but I do not think there is much fear of this as manila hemp is not adversely affected by water.

Charts for the Proper Cutting Speed of Steel

By H. M. BRAYTON
Captain Ordnance Department, U. S. A.

Few men, no matter what their education, enjoy working out involved mathematical calculations. Hence the large and growing use of charts as time and labor savers. The three charts given here afford a short method of determining the relation between tensile strength, elongation and cutting speed as well as that between feed, depth of cut and surface speed.

THE whole trend of the modern shop organization is toward the maximum possible production with the machines and men available. There are two ways of getting the most out of a machine: First, to keep that machine running 24 hours a day, and second, to make it do the maximum of work while it is running by applying scientific methods to the work.

The science of shop management is still in its infancy and much still remains to be done in this very important field. We have available, however, the great work of F. W. Taylor who in his paper, "On the Art of Cutting Metal," gives much valuable information which, if properly applied, is certain to yield results. Mr. Taylor gives in his paper several formulas showing the relation between the desired surface speed of the work, the strength of the metal and the percentage of elongation. In addition to this he also gives a formula for the relation between the surface speed of the work, the depth of cut and the feed. Unfortunately these formulas are rather complicated and sometimes require the use of logarithms for their solution. This means that the average shopman will not take the time to apply them, and even the man who is planning the work will avoid a complicated formula if he can. The purpose of this article is then to chart two of these common formulas so that a man unfamiliar with mathematics can apply them to his work

The physical properties of the steel being cut are practically always known and the following formula gives the proper cutting speed:

$$V = \frac{125\left(1 - \frac{215}{(15 + E)^2}\right)}{\sqrt{\frac{S}{10{,}000}} - 3 - 0.9} \qquad (1)$$

Where V = Standard cutting speed,
E = Percentage of elongation of specimen 2 in. x ½ in.,
S = Tensile strength in lb. per square inch.

This formula is charted in Fig. 1, and although the formula is rather complicated it will be observed that the chart is easy to read, all that is necessary to solve for V when E and S are known being to lay a straightedge across the chart connecting the known values of S and E as found on their respective outside scales when the corresponding value of V will be cut out on the central diagonal scale.

To illustrate this an example has been taken on the chart. Assume you desire to cut a steel which

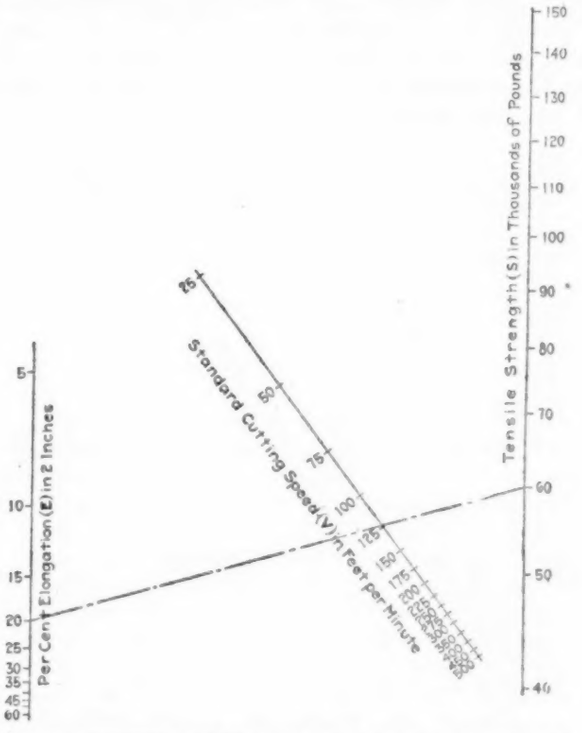


FIG. 1. CUTTING SPEED IN RELATION TO TENSILE STRENGTH AND PERCENTAGE OF ELONGATION OF METAL

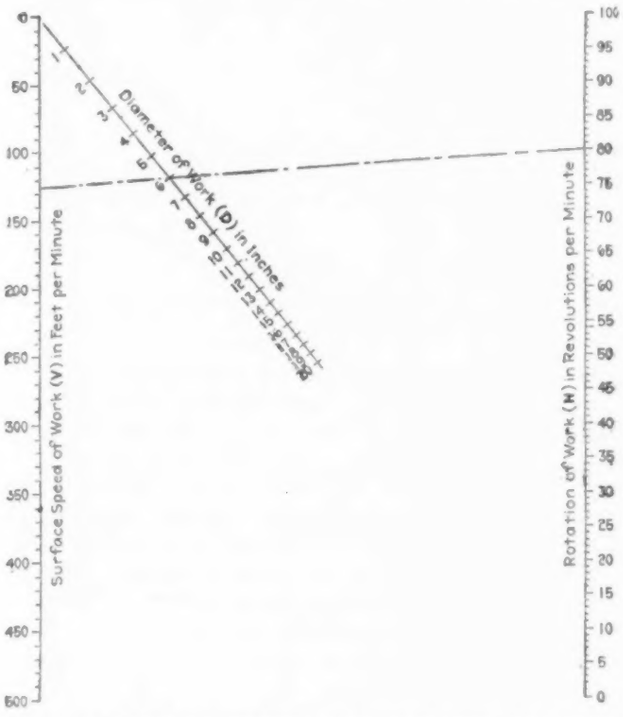


FIG. 2. RELATION BETWEEN SURFACE SPEED, ROTATION AND DIAMETER OF WOKR

has a tensile strength of 60,000 lb. per square inch and an elongation of 20 per cent. The dash-dot line on the chart connects these values and it will be seen that this line cuts out a value of approximately 125 on the center scale. This means that the steel can be cut at a maximum surface speed of 125 ft. per minute. In a similar manner any one of the three variables in this formula may be found if the other two are known. This chart can be kept on the desk ready for use and should be found of value to anyone planning shop work of this kind.

The surface speed of lathe work varies of course every time a cut is taken and the diameter decreased. The surface speed of a particular diameter in a certain

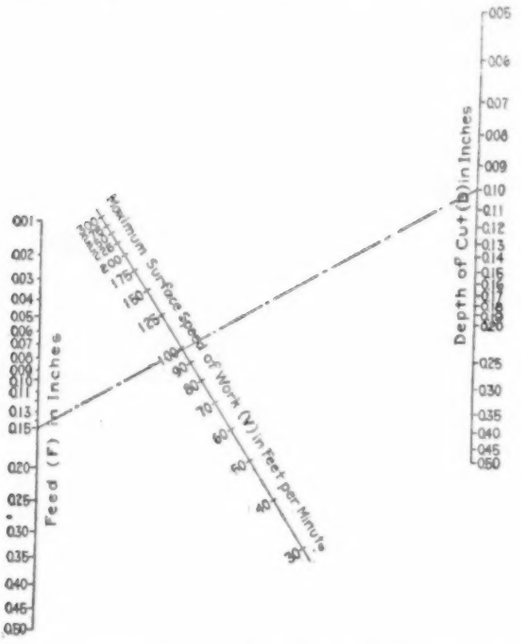


FIG. 3. RELATION BETWEEN FEED, DEPTH OF CUT AND SURFACE SPEED

lathe is seldom known without going through a rather lengthy calculation. The rotational speed of the spindle, however, is known and does not change except at the will of the operator.

In connection with the above chart it is highly desirable to have some means of quickly determining what the surface speed is or what revolutions per minute the spindle must turn with a given diameter of work in order to give the desired surface speed. This relation is of course very simple and is given by

$$N = \frac{3.82V}{D}$$

Where N = Speed of spindle in revolutions per minute,
V = Surface speed of work in feet per minute,
D = Diameter of work in inches.

This formula is charted in Fig. 2 and is read exactly the same as the chart in Fig. 1. The dash-dot line illustrates a surface speed of 125 ft. per minute and a diameter of work of 6 in., and by connecting these values on the left-hand and center scale respectively we find that the right-hand scale shows a spindle speed of 80 r.p.m. to be necessary.

The following formula is also given by Mr. Taylor for the relation between the cutting speed, the feed and the depth of cut for the standard 1¼-in. tool:

$$V = \frac{195}{F^{0.417}D^{0.357}} \qquad (3)$$

Where V = Cutting speed in feet per minute,
F = Feed in inches,
D = Depth of cut in inches.

The obvious difficulty in applying this formula lies in the fact that it becomes necessary to use logarithms in solving these variables raised to an uneven power. To eliminate the mathematics the chart shown in Fig. 3 has been plotted. This chart is read exactly the same as the two previous ones. The dash-dot line illustrating how to read the chart cuts out an assumed value of 0.15 in. for the feed and 0.10 in. for the depth of cut. This shows on the center scale that a surface speed of about 97 ft. per minute is desirable.

A suggested procedure in the use of these three charts would then be to determine first the maximum allowable cutting speed of the steel under consideration from Fig. 1. If the physical properties of the steel are not known they can easily be determined. With the cutting speed determined establish a proper feed, and from Fig. 3 solve for the proper depth of cut. Then from Fig. 2 the spindle-speed required to give this surface speed can be determined for the diameter used. In this connection it would be well to make a little table for the use of the lathe operator showing how he must change his spindle speeds as the diameter of the work decreases.

Taper-Boring Tool for Turret Lathe

BY R. P. DEANE

There are some points about the taper-boring tool, shown by W. H. Addis on page 383, that I do not think are quite clear.

First, I see no means provided to prevent the boring bar from revolving from the thrust of the cut. Second, I assume the working surface of the inclined guide *G* to be straight. If this is true, how can it bore a true taper, as the eccentric raises and lowers the point of the tool above or below center, as it moves the bar on an arc of a circle instead of in or out on a straight line; also, the further the eccentric is turned the less the lateral movement per degree of revolution.

In either boring or turning a taper, if the point of the cutting tool is not on the center, the sides of the taper will be concave or convex. Of course, this gets more apparent either with the greater the angle or the smaller the hole bored.

I believe this could be overcome by making the working surface of the inclined guide a generated curve to compensate for the aforementioned trouble.

The result of boring or turning a taper with the tool above center was brought very forcibly to my mind in the first of my apprenticeship. I was given a piece to bore and a plug to fit to the hole on a rather sharp taper. I bored the piece with the compound rest and, without changing the setting of same, turned the plug, but in neither case did I pay any attention to the exact height of the tool. I was a very surprised boy when I discovered that my tapers did not fit nor do I think I really understood the reason until some time later when it was explained, I believe, in the *American Machinist*.

The Equation of the Involute Simplified

By N. FINKELSTEIN

The mathematical discussion presented here, unlike many such dissertations, takes a complicated formula and reduces it to a simple and easily applied form instead of starting with perfectly apparent truths and winding up with a three-line formula that no one but a mathematics professor could handle. The use of this simple expression in involute gear-tooth problems should be a help to designers who are working along these lines.

SINCE the adoption of the involute form of gear tooth enough investigations and experiments have been performed by gear specialists to make possible the design of gears of increased strength, durability and quietness of operation. The last characteristic is of particular importance for gears used in automobile transmissions and differentials. Apparently little has been written on the mathematics of the involute curve as applied to gear teeth, perhaps because of its intricacy. It is the purpose of this article to show that the equation can be greatly simplified and easily applied to the solution of practical problems.

The present discussion will be confined to the derivation of formulas for finding the thickness of the tooth

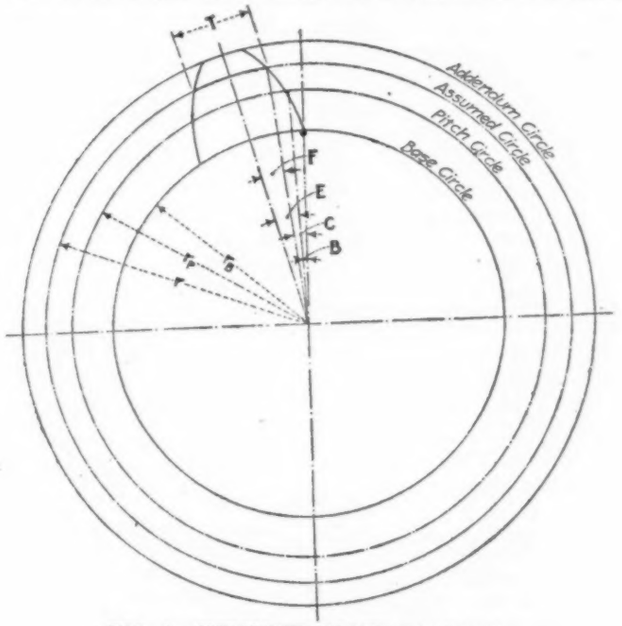


FIG. 1. INVOLUTE TOOTH DIAGRAM

at any point from the base circle to the point of the tooth. The following symbols will be used, see Fig. 1:

r_P = pitch radius;
r_B = base radius;
r = any radius;
A = pressure angle;
B = angle between base radius and pitch radius;
C = angle between base radius and assumed radius;
D = angle between the origin of the involute curve and the center of curvature of any point in the involute, Fig. 2;
D_r = same angle measured in radians;
E = angle measured by half the circular thickness of the tooth at the pitch line;
F = angle measured by half the circular thickness of the tooth at the assumed point;
T = chordal thickness of the tooth at any point

Derivation of Formulae

The general equation of the involute curve with respect to rectangular coördinate axes is:

$$x = a \cos D + aD_r \sin D \quad (1)$$

$$y = a \sin D - aD_r \cos D \quad (2)$$

in which a is the radius of the generating circle, or according to our notation, r_B.

$$\frac{y}{x} = \frac{\sin D - D_r \cos D}{\cos D + D_r \sin D} = \tan Z \quad (3)$$

where Z is an angle included between the base radius and any radius on the profile of the tooth. When the radius becomes equal to the pitch radius, $Z = B$, and when it becomes equal to the assumed radius, r, $Z = C$.

Dividing numerator and denominator of formula 3 by cos D we get

$$\tan Z = \frac{\dfrac{\sin D}{\cos D} - \dfrac{D_r \cos D}{\cos D}}{\dfrac{\cos D}{\cos D} + \dfrac{D_r \sin D}{\cos D}}$$

$$= \frac{\tan D - D_r}{1 + D_r \tan D} \quad (4)$$

Formula 4 can be further simplified by substituting for D_r an angle whose tangent is D_r ($\tan^{-1} D_r$). Let this angle be G, then $\tan G = D_r$ and substituting this in formula 4 we get

$$\tan Z = \frac{\tan D - \tan G}{1 + \tan D \tan G}$$

$$\text{or } \tan Z = \tan (D - G) \quad (5)$$

$$\text{hence } Z = D - G \quad (6)$$

$$\text{but } \tan G = D_r, \text{ then } G = \tan^{-1} D_r$$

$$\text{and } Z = D - \tan^{-1} D_r \quad (7)$$

This is the general formula for finding the angle between the base radius and any radius on the profile of the tooth.

In Fig. 2, which shows the development of the involute curve, oa is the radius of the generating circle; ka

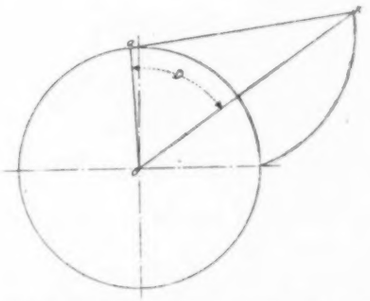


FIG. DEVELOPMENT OF INVOLUTE CURVE

is a tangent drawn from any point k on the profile of the curve, and ok is the radius to the assumed point k. In the right-angled triangle oak,

$$\overline{ok}^2 = \overline{oa}^2 + \overline{ak}^2 \quad (8)$$

but from the way the involute curve is developed,

$$ak = oa \times D_r \quad (9)$$

$$\text{and } \overline{ak}^2 = \overline{oa}^2 \times D^2 \quad (10)$$

substituting this in formula 8 we get

$$\overline{ok}^2 = \overline{oa}^2 + \overline{oa}^2 \times D_r^2 \quad (11)$$

by transposition, we get

$$\overline{oa}^2 \times D_r^2 = \overline{ok}^2 - \overline{oa}^2 \quad (12)$$

$$\text{then } D_r^2 = \frac{\overline{ok}^2 - \overline{oa}^2}{\overline{oa}^2} \quad (13)$$

$$\text{and } D_r = \sqrt{\left(\frac{ok}{oa}\right)^2 - 1} \quad (14)$$

according to our notations, $ok = r$

$$\text{and } oa = r_B \text{ hence } D_r = \sqrt{\left(\frac{r}{r_B}\right)^2 - 1}$$

To find D, multiply D_r by $\frac{120}{\pi}$ or 57.296; therefore

$$D = 57.296 \sqrt{\left(\frac{r}{r_B}\right)^2 - 1}$$

where r = the pitch radius. The formulas for D and D_r can be further simplified, for $r_b = r_p \times \cos A$. Making the necessary substitutions in the formula for D_r we have

$$D_r = \sqrt{\left(\frac{r_p}{r_p \times \cos A}\right)^2 - 1}$$

$$= \sqrt{\left(\frac{1}{\cos A}\right)^2 - 1}$$

$$= \sqrt{\sec^2 A - 1}$$

$$= \tan A \quad (15)$$

$$\text{and } D = \frac{180}{\pi} \times \tan A \quad (16)$$

In other words the angle between the origin of the involute curve and the center of curvature of the point where the pitch circle intersects the involute curve is constant for the same pressure angle and is equal to the product of the constant $\frac{180}{\pi}$ and the tangent of the pressure angle.

When r = the pitch radius,

$$Z = B$$

$$\text{and } A = \tan^{-1} D_r$$

$$\text{hence } B = \frac{180}{\pi} \tan A - A \quad (17)$$

This formula shows that B varies only with the pressure angle. It is therefore possible to figure B for several pressure angles and use this value for all problems that may arise.

Belows is given the value of B for four different pressure angles.

For $14\frac{1}{2}°$, $B = \frac{180}{\pi} \tan 14\frac{1}{2}° - 14\frac{1}{2}° = 0° 19' 2''$

$17\frac{1}{2}°$, $B = \frac{180}{\pi} \tan 17\frac{1}{2}° - 17\frac{1}{2}° = 0° 33' 55''$

$20°$, $B = \frac{180}{\pi} \tan 20° - 20° = 0° 51' 14''$

$22\frac{1}{2}°$, $B = \frac{180}{\pi} \tan 22\frac{1}{2}° - 22\frac{1}{2}° = 1° 13' 57''$

Example

Given a spur gear with 17 teeth, 6–8 pitch, 20° pressure angle. To find the thickness of the tooth at a distance of $1\frac{5}{8}$ in. from the center.

$$r_P = \frac{17}{2 \times 6} = 1.4166 \text{ in.}$$

$r_B = r_P \times \cos 20° = 1.4166 \times 0.93969 = 1.3312$ in.

$r = 1.4688$ in.

$$D_r = \sqrt{\left(\frac{1.4688}{1.3312}\right)^2 - 1} = 0.46637 \text{ in.}$$

$C = 57.296 \times 0.46637 - \tan^{-1} 0.46637$
$= 26° 43' 16'' - 25° = 1° 43' 16''$

$E = \frac{90}{17} = 5° 17' 39''$

$B = 0° 51' 14''$ (For 20° pressure angle)

$F = E + B - C = 5° 17' 39'' + 0° 51' 14'' - 1° 43' 16''$
$= 4° 25' 37''$

$T = 2 \times r \times \sin F$
$= 2 \times 1.4688 \times \sin 4° 25' 37''$
$= 2 \times 1.4688 \times 0.07719 = 0.2267$ in.

In figuring bevel gears, the virtual pitch radius must be taken for r_P which is the pitch radius divided by the cosine of the pitch angle.

In conclusion it should be stated that a measurement of the thickness at the point of a tooth of a small gear is worth less as a check of the form of the involute because of the variation in turning of the blanks and the distortion due to heat-treatment. For large gears where the usual testing facilities are not available these formulas will enable inspectors to get an approximate check of the thickness at the tooth point by calculation and measurement.

What Is a High-Grade Machine?

The following letters give the impressions and convictions of leading machine-tool builders as to what constitutes a high-grade machine:

W. K. Millholland Machine Co, Indianapolis, Ind.

We found that in order to arrive at an answer it was first necessary for us to analyze the subject "High-Grade Machine," which we did as follows:

First, the design must be suitable for the duty to be performed, must be well proportioned and pleasing to the eye; second, the material must be suitable for the strain imposed by the duties performed; third, the workmanship must be first class; fourth, the performances must be satisfactory; fifth, the maintenance must be low in comparison with the duty performed; sixth, the life should be long enough to bring an adequate return on the initial investment.

We believe that any machine embodying all of the above six points is entitled to be called a high-grade machine.

W. K. Millholland.

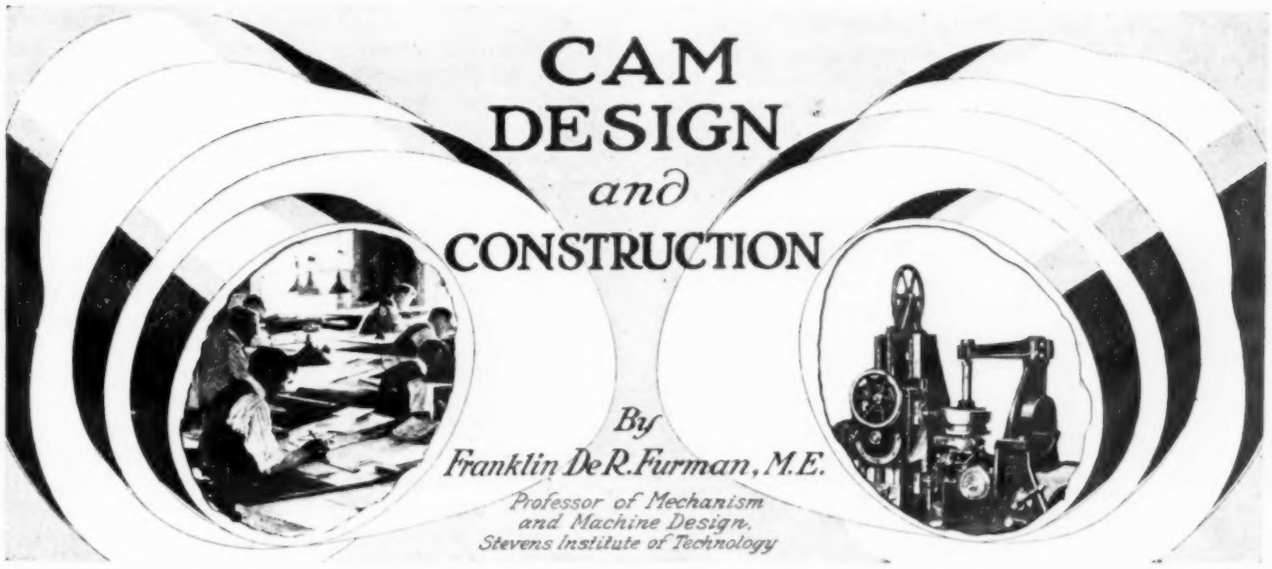
The National Acme Co., Cleveland, Ohio

Expressed in the simplest words, it is our impression that a high-grade machine is one that has won a reputation in the trade for the accuracy of its product and for the length of time it will stand up. In other words, I believe that the term "high grade" is derived more from the expressed experience of users than from a thorough analysis of any new machine which might be just going onto the market, although of course both might be equally high grade.

Of the several angles referred to in your article, I believe that the element of accuracy stands paramount in the machine-tool world when speaking of high-grade machines. Some types of tools are very rapid, but are not intended to turn out high-grade work; that is, work requiring close tolerances. Other machines are not particularly fast, but are known for their exceptional precision.

Therefore, it seems to the writer that the general conception of a high-grade machine is one that has gained a reputation of turning out duplicate work consistently and with minimum repair.

L. E. Honeywell, Advertising Manager



VII. The Logarithmic Base Curve

The previous articles dealt with the simpler base curves which are in common use and with their elementary applications to various cams. In this and succeeding articles some other base curves are proposed, and still others that are generally known are treated in a systematic way so as to obtain definite results. In this issue the logarithmic curve, which gives the smallest possible cam for given data, is considered.

THE all-logarithmic base curve, Fig. 60, gives the smallest possible cam for a given pressure angle. It differs from all other cam base curves in that it gives the maximum pressure all the time that the follower is moving, whereas the others give a maximum pressure angle for an instant only. The construction of the all-logarithmic cam is explained in the following paragraphs:

Problem 16. Required an all-logarithmic cam causing: (a) The follower to rise 1 unit in 60 deg. turn of the cam; (b) the follower to fall 1 unit in 60 deg. turn of the cam; (c) the follower to remain stationary for 240 deg. turn of the cam; (d) a uniform pressure angle of 30 deg.

A General Analysis for the method of procedure in solving an all-logarithmic cam problem is:

1. To construct a logarithmic spiral having a constant normal angle of 30 deg. The spiral is shown at *BH*, Fig. 61, and the constant angle is noted at *JDK* where *DK* is a radial line and *DJ* a line normal to the curve.

2. To lay out the assigned working angle, during which the follower motion takes place, on a piece of tracing cloth or tracing paper, as at *b* in Fig. 62.

3. To mark on each leg of the angle a scale with which to measure the follower's motion, as *O'M* and *O'N* in Fig. 62.

4. To lay the tracing cloth, represented by Fig. 62, over the logarithmic spiral Fig. 61, with the apex *O'* of the angle always at the pole *O* of the spiral, and to rotate the tracing cloth until the two legs of the angle cut the spiral at such points that the difference in length of the two legs is equal to the assigned follower motion. This is illustrated in Fig. 61 where the shaded area represents the tracing cloth with the assigned angle of 60 deg. shown at *b*, while *OC* minus *OA* equals the assigned follower motion of 1 unit.

5. To draw the included part of the logarithmic spiral *AC* which will be part of the actual cam contour, as shown at *AC* in Fig. 63.

The detail construction necessary to apply the above analysis to problem 16 is as follows: Construct a logarithmic spiral with a constant normal angle of 30 deg. This may be done mathematically by laying off computed values or it may be done graphically. In the mathematical method the first step is to solve the following equation:

$$\frac{r'}{r} = 10^{0.4343 \frac{\pi}{180} b \tan (90° - a)}$$

where a is the assigned pressure angle and b is a unit angle taken at any value which may be conveniently used later in starting the drawing of the curve. The values of r and r' are represented at *OD* and *OH* respectively, Fig. 61. The angles a and b are also shown. A convenient angle to assume for b in general is 60 deg. and it is so taken in this problem. Then $\frac{r'}{r}$ equals the number whose logarithm is $0.4343 \times \frac{3.14}{180} \times 60 \times \tan (90 \text{ deg} - 30 \text{ deg.})$. Solving, the value of the logarithm is 0.2623 and the number corresponding to this is 1.83. Therefore $\frac{r'}{r} = 1.83$ and *OH*, Fig. 61, is made 1.83 times *OD*, the included angle being 60 deg. in accordance with the above assumption for b. The length *OD* may be taken any length in starting the construction of the curve. The two points of the curve may now be laid down as at *D* and *H* with *O* as the pole.

Intermediate points on the logarithmic spiral as at *G* may be found by bisecting the angle *DOH* and making *OG* a mean proportional between *OD* and *OH*. Then

$$OD : OG :: OG :: OH$$

If *OD* is taken as 3 units then $OG = \sqrt{3 \times (1.83 \times 3)} = 4.06$.

To find points on the curve at closer intervals bisect

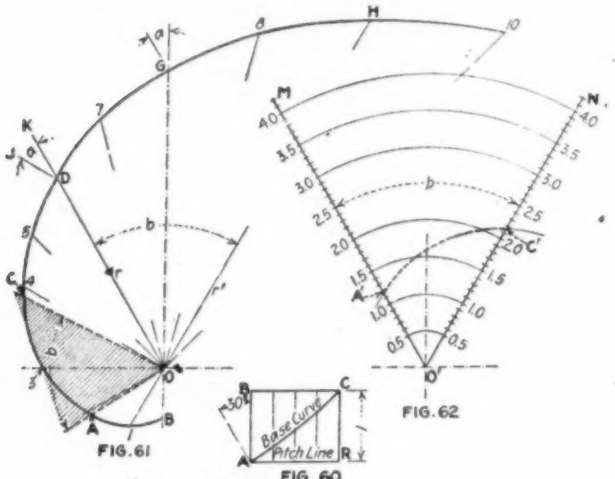
angle *DOG* and find the mean proportion *O7* which is equal to $\sqrt{3 \times 4.06} = 3.52$. To find other points outside of a given angle, such as at *5*, lay off the angle *DO5* equal to angle *DO7* and make *O5* a fourth proportional as follows:

$$O5 : OD :: OD : O7$$

$$\text{Then } O5 = \frac{3^2}{3.52} = 2.58$$

If points are desired still closer together or if it is desired to extend the curve in either direction it may be done by the above described processes, or it may be done graphically, as will be described presently.

The next detail step in the solution of problem 16 is to draw an angle *MO'N*, Fig. 62, on tracing cloth equal



FIGS. 60 TO 64. CAMS WITH LOGARITHMIC CURVES

Fig. 60—All logarithmic base curves. Fig. 61—Logarithmic curve giving constant pressure angle of 30 deg. Fig. 62—Assigned working angle to be drawn on tracing cloth. Fig. 63—Problem 16, all-logarithmic cam for assigned data. Fig. 64—Graphical method for finding intermediate points on logarithmic curve.

to the assigned angle of 60 deg. as given at (a) in the data, and lay off a scale on each leg of the angle as shown. Then lay Fig. 62 over Fig. 61, *O'* always at *O*, and rotate the tracing cloth until the curve *BH* intercepts the lines *O'M* and *O'N* at such points that *O'C'* minus *O'A'* equals the assigned follower motion, which is one unit, as stated at (a) in problem 16. This occurs when Fig. 62 is at the position shown by the section lines in Fig. 61 where *OA* equals 1.18 and *OC* equals 2.18. The intercepted part *AC* of the logarithmic curve becomes a portion of the cam pitch surface as shown at *AC* in Fig. 63, and its distance from the center of rotation of the cam is the same as the distance from the curve to the pole of the spiral in Fig. 61.

Other portions of the cam surface are found in a similar manner. As shown at *A*, *E* and *C*, Fig. 63, the pressure angle is 30 deg. at all points.

Graphical method of finding intermediate points on the logarithmic spiral.—From any point *O* of a straight line, Fig. 64, lay off *OD* and *OH* in opposite directions, *OD* and *OH* being the values obtained by computation, as explained in preceding paragraphs and shown in Fig. 61. At *O*, Fig. 64, erect a perpendicular line. Find the midpoint *O*, on the line *DH*, and with this as a center for the compass draw the semicircle *DGH*. Then *OG* will be a mean proportional between *OD* and *OH* and may be laid out as the ordinate of the logarithmic spiral, as at *OG*, Fig. 61, where *OG* bisects the angle *DOH*. Fig. 64 is drawn to one-half the scale of Fig. 61.

To find a fourth proportional graphically proceed as follows: Lay off the two known values *OD* and *OH*, which are shown in Fig. 61, at right angles to each other, as shown at *OD'* and *OH* in Fig. 64. Find the point O_2 on *OH* that is equidistant from *D'* and *H*, and with this as a center draw the semicircle *HD'3*, giving the length *O3* as the fourth proportional. This latter distance is laid off at *O3* in Fig. 61 where the angle *DO3* is equal to angle *DOH*.

Graphical method for constructing a logarithmic spiral having a given constant normal angle.—This method, referred to in a preceding paragraph, is based on the following theoretical property of the logarithmic spiral, namely, that all pairs of radiants having a common difference embrace equal lengths of arcs on the curve.

The principle stated in the previous paragraph may be graphically applied only approximately, but with all necessary precision, by drawing the lines *MP* and *PN*, Fig. 65, making the desired angle with each other. This angle will be 30 deg. if a curve having a constant normal angle of 30 deg. is required, 40 deg. if a constant pressure angle of 40 deg. is required, etc. From a point *O*, where the vertical intercept *OD* is equal to about the estimated short radius of the cam, draw a series of equidistant vertical lines as at *B*, *C*, *E*, etc. With *BF* as a radius and *O* as a center draw the short arc *1*; with *DF* as a radius and *D* as a center draw arc *2*. The intersection of arcs *1* and *2* will give the point *H* on the curve. Again, with *CG* as a radius and *O* as a center draw arc *3*, and with *FG* (equal *DF*) as a radius and *H* as a center draw arc *4*. The intersection of arcs *3* and *4* will give a second point *L* on the logarithmic spiral. It will now be noticed that the two pairs of radiants *HO-DO* and *LO-HO* have a common difference, and that the logarithmic arcs *DH* and *HL* are equal (approximately), which accords with the general principle laid down in the preceding paragraph.

To be exact, in the matter of the graphical construction of the logarithmic spiral, it must be noted that it is the chords from *D* to *H* and from *H* to *L* that are equal according to this method of construction, and not the arcs as they should be theoretically; but where the vertical construction lines are taken close together and where the distance *DF* is therefore small the error in the curve is negligible. In the present case the ultimate distance *OR* when drawn with average care to a scale several times that shown in Fig. 65 varied from the computed value by less than 0.01. The part of the curve from *D* to *Q* will depart from theoretical values faster than the part from *D* to *R*, due to the sharper curvature of *DQ*, but the effect of this may be overcome, if desired, by making the vertical construction lines to the right of *OD* closer than those to the left of *OD*.

Logarithmic-combination cam.—The all-logarithmic cam has sharp surface angles as may be noted at *A* and *C*,

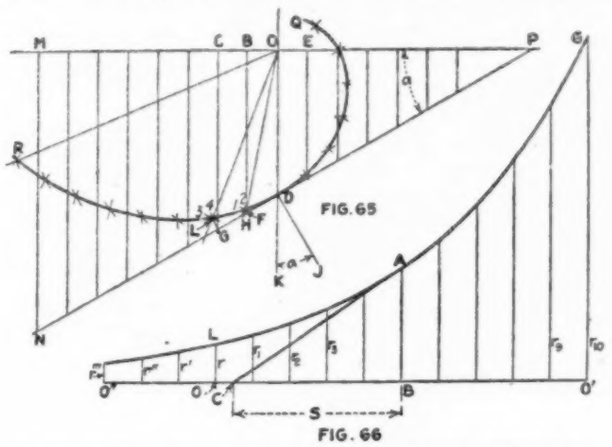
Fig. 63, and gives sharp starting and stopping velocities and requires that a V-edge follower be used for correct theoretical results. The logarithmic-combination curve overcomes these objections with very little sacrifice in the matter of size of cam by simply easing off the angular surfaces formed by the all-logarithmic curve by means of parabolic base arcs which give the best results.

A cam in which this has been done is shown in Fig. 68 where the curves *AY* and *ZC* are arcs of a parabola base and the center portion *YZ* is an arc of a logarithmic curve. To illustrate an actual case a problem having the same general data as problem 16 will be discussed in the following paragraphs:

Problem 17. Required a logarithmic-combination cam causing the follower to: (a) Rise 1 unit in a 60 deg. turn of the cam; (b) fall 1 unit in a 60 deg. turn of the cam; (c) remain stationary for a 240 deg. turn of the cam and (d) the maximum pressure angle to be 30 deg. and the easing-off base curves to be parabolic arcs.

A general analysis of the method of procedure in solving problems of this kind is:

1. To draw a general logarithmic curve on rectangular coördinates, the longest and shortest ordinates of



FIGS. 65 AND 66. CONSTRUCTION OF LOGARITHMIC CURVES

Fig. 65—Graphical method for constructing a logarithmic curve having a constant normal angle. Fig. 66—General logarithmic curve showing subtangent, useful in solving a wide range of logarithmic cam problems.

which will correspond to the estimated longest and shortest radii of the cam or the longest and shortest radii of a series of cams, if a series should happen to be under design.

2. To compute the length of rectangular cam chart, as directed later, and to draw the rectangle on tracing cloth or tracing paper.

3. To construct parabolic arcs within the rectangular cam chart.

4. To place the cam chart as now drawn on the tracing cloth over the logarithmic curve, so that the logarithmic curve will be tangent to the two parabolic arcs while the bottom line of the chart is parallel to the abscissa of the logarithmic curve. The distance between the bottom of the chart and the abscissa will be the shortest radius of the cam.

The first step in the detail of the solution of problem 17 is to construct a logarithmic curve on rectangular coördinates, as in Fig. 66. This curve is a perfectly general one, and if it drawn with a wide enough range of ordinates it will do for all possible logarithmic-combination cams independently of all specific data. To construct the logarithmic curve draw a horizontal abscissa line *OO'*, Fig. 66, and erect a series of ordinates one unit apart as on both sides of *r*, making their length a geometrical progression. To do this make the first ordinate drawn, say *OL*, equal to 1 unit and all succeed-

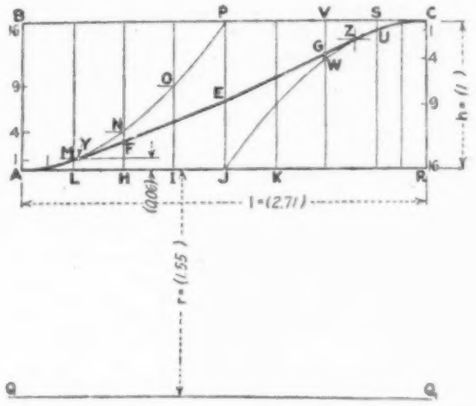


FIG. 67. RECTANGULAR CHART USED IN DESIGN OF LOGARITHMIC COMBINATION CAM

ing ordinates such as r_1, r_2 longer than the preceding ordinate by using any common multiplier throughout; also all preceding ordinates such as r', r'', if they are necessary, shorter by the inverse of the same ratio. For example, if *OL* equals 1 and if the common multiplier is taken as 1.25 (it may be any convenient number) then $r_1 = 1 \times 1.25 = 1.25$; $r_2 = 1.25 \times 1.25 = 1.5625$; $r_3 = 1.5625 \times 1.25 = 1.953$, etc.; also $r' = 1 \times \frac{1}{1.25} = 0.8$, $r'' = 0.8 \times \frac{1}{1.25} = 0.64$, etc. The lengths should be accurately computed up to the length of the maximum radius of the largest cam that is likely to be used and the curve *LG* carefully drawn.

The length of the subtangent s in Fig. 66 is next found by the formula, $s = \frac{0.434}{\log.\ m}$ where *m* is the common multiplier used in laying out the logarithmic curve *LG*. Since the value of *m* is 1.25 in this problem $s = \frac{434}{0.097} = 4.48$. This value of the subtangent may also be found graphically by drawing tangents to the logarithmic curve, by eye, at several points and taking an average of the subtangents thus found. This average value will probably be close enough for most practical work. The tangent line at *A* is shown at *AC*, Fig. 66. The length of the subtangent *BC* will be the same for each tangent line if it is accurately drawn.

A special form of rectangular diagram, Fig. 67, depending on the data is now constructed, its length being

$$l = \frac{b \times s \tan a}{180}$$

where

l = length of diagram;
b = assigned angle of action;
s = length of subtangent of the logarithmic curve as found in the preceding paragraph;
a = assigned pressure angle.

Taking the figures from the data for this problem and

the value of s as found and substituting in the above formula

$$l = \frac{60 \times 3.14 \times 4.48 \times 0.577}{180} = 2.71.$$

The height of the diagram is the continuous motion of the follower in one direction and is one unit in this problem as indicated at *RC*, Fig. 67. Draw the rectangle, as shown at *ARC*, at or near the top of a piece of tracing cloth or tracing paper, leaving a length under it equal at least to what the short radius of the cam is estimated to be.

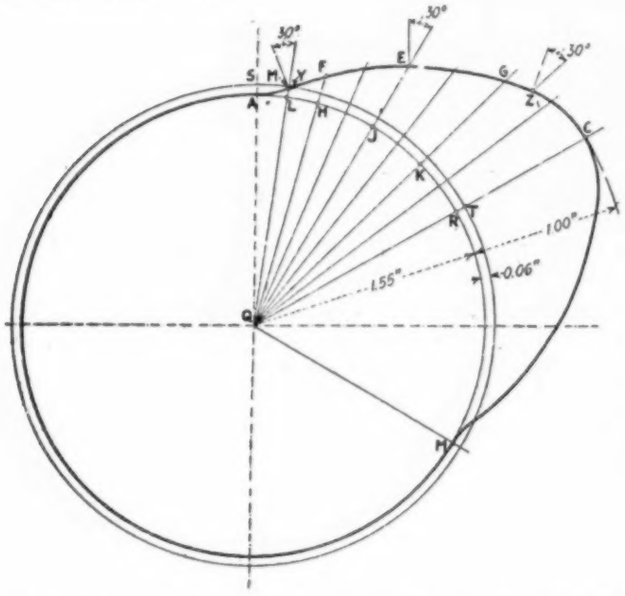


FIG. 68. PROBLEM 17, LOGARITHMIC-COMBINATION CAM WITH PARABOLIC ARCS AT ENDS

Parabolic easing-off arcs for logarithmic-combination cam.—The rectangular diagram is now divided into at least eight equal parts, which are sufficient for practice problems, but in practical applications at least 16 divisions should be taken. A diagram divided into eight parts is shown in Fig. 67. Construct a parabola with vertex at *A* and passing through the midpoint *P*. This is done in the ordinary way as explained in detail in Article II and briefly reviewed as follows: Divide *AB* into a series of equal parts, the total number of parts being equal to the square of the number of construction spaces between *A* and *J*. In this problem there are four construction spaces and so *AB* is divided into 16 equal parts; and the first, fourth and ninth division points are projected horizontally to *M*, *N* and *O*, which are points on the parabola. Construct the similar parabolic arc *CJ* in the same way.

Lay the rectangular diagram constructed as above on tracing cloth over Fig. 66 and manipulate it, always with the line *AR*, Fig. 67, parallel with the line *OO'*, Fig. 66, until the logarithmic curve *LG*, showing through the tracing cloth, is tangent to the two parabolic arcs. This occurs in this problem when *AR* is 1.55 units above *OO'*, and 1.55 is therefore the shortest radius of the pitch surface of the cam. For precision work later on mark the points *Y* and *Z*, Fig. 67, where the logarithmic arc comes tangent to the parabolic arcs. Fig. 66 is shown in the illustration much reduced in scale in comparison with Fig. 67.

The cam for problem 17 may now be constructed, drawing first the circle, Fig. 68, having a radius *QA* of 1.55 units. Lay out the angle *AQC* equal to the assigned 60 deg. and divide it into equal spaces by as many radial lines as there are ordinates in Fig. 67. Transfer the ordinates *LM*, *HF*, etc., from Fig. 67 to Fig. 68 and draw the pitch surface of the cam through the points *A*, *M*, *F*, etc. The working surface would be a parallel curve distant from the pitch surface by the radius of the follower roller. With this cam there would be uniform acceleration of the follower from *A* to *Y* where the pressure angle reaches 30 deg. This angle remains constant until *Z* comes into action when it begins to decrease to zero at *C*.

Position of pitch circle of logarithmic-combination cam.—If it is desired to know the pitch circle of the cam it may be found by noting in Fig. 67 where the logarithmic arc comes tangent to the starting parabolic arc. This is at *Y*, and in this problem it is 0.06 unit from the bottom of the diagram. This distance is laid off as *AS*, Fig. 68, to obtain the pitch circle *ST*. If it is desired further to obtain the cam chart which is necessary to draw the velocity and acceleration diagrams it may be found as represented in Fig. 69 where the length *DF* is equal to the length of the arc *ST* in Fig. 68 where both are drawn to the same scale. *DF* is the pitch line of the chart and *AR* is 0.06 unit below it, this value being taken from Fig. 67. The lengths of the ordinates *LM*, *HF*, etc., in Fig. 69, are equal to those in Fig. 67 when both figures are drawn to the same scale. It will be noticed that no factor is given in connection with the cam chart for the logarithmic cam as it is for other cams. There is no constant factor; it varies with each problem.

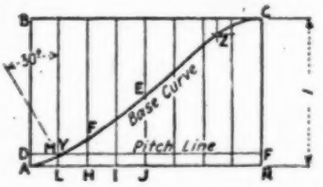


FIG. 69. CAM CHART FOR LOGARITHMIC-COMBINATION CAM

The rates of acceleration and retardation that will be given by the cam at the ends of the stroke are arbitrarily determined in Fig. 67 by causing the parabolic arcs to pass through *P* and *J*. With the parabolic arcs so taken good average results will be obtained, as compared with other small cams. If different accelerations and retardations are desired for the follower the points *P* and *J* may be located further up or further down and the cam will be either smaller or larger.

High-Speed Steel as a Material for Cold Chisels

BY A. R. DURANT

The most satisfactory cold chisels I have found are some which were forged from high-speed-steel toolbits. The square stock was first hammered to an octagon shape and then drawn to the form of an ordinary chisel.

While forging high-speed steel, the work should be kept at yellow heat to avoid cracking and as the steel cools quite rapidly, not much hammering can be done at one time.

As these alloys are practically self-hardening it is unnecessary to quench the tools. Simply grinding them to shape makes them ready for use.

I find these cold chisels work particularly well when chipping tool steel, cutting spring wire, etc., and can be sharpened with an oilstone after considerable use.

Turret Lathe and Other Tools for Railroad Shop Use

By FRANK A. STANLEY

The tools illustrated and described in this article are for machining bearings for armature shafts; hollow-milling round articles; boring rod brasses and turning and boring slip rings for eccentrics; shaping rod brasses, etc.

SOME tools used in machining brass and bronze work in railroad shops are illustrated herewith. These pertain principally to the turret lathe, engine lathe and shaping machine.

Fig. 1 represents a box tool with adjustable boring bar. The work on which it is employed is a phosphor-bronze casting, Fig. 2, with an outside diameter of 2.249 in. and a bore of 1½ in. The smaller bearing of

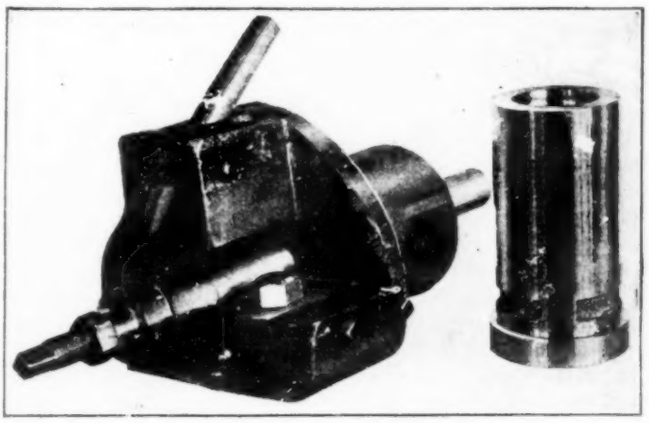


FIG. 1. BOX TOOL WITH ADJUSTABLE BORING BAR

the two in the drawing is 4 in. long, has a diameter of 1.999 in. and a bore of 1¼ in. and there is a minus allowance of one-half thousandth from the bore and external diameters.

These bearings are used with a car-lighting system, and the material is made of copper, 79.70 per cent.; lead, 9.50 per cent. (limits, 8 to 11 per cent.); tin, 10.00 per cent. (limits, 9 to 11 per cent.), and phosphorous, 0.80 per cent. (limits, 0.7 to 1.0 per cent.). Total of substances other than the above not to exceed 1.0 per cent.

Both bearings, it will be observed, are formed with the oiler opening through the wall, leaving the external and interior surfaces interrupted at the middle for about one-half the circumference.

Construction of the Box Tool

The shank of the cast box tool, Fig. 3, is bored with a taper hole, smallest at the rear end, which fits over a similar portion on the central bar, which extends completely through the box tool and projects at both ends. The taper is of an easy angle of slope and the tool is held firmly in the taper seat by a locknut at the rear.

The arrangement of boring and turning tools in the box holder and bar is shown clearly.

The boring tool is adjustable for diameter of work, the method of adjustment being by application of the pointed screw *A*, Fig. 3, which bears against the beveled inner ends of the two coring cutters *B*, these being made of ¼-in. square stock fitted crosswise of the boring bar.

Each short cutter has a binding screw and the adjusting screw *A*, when properly set, is locked by means of the nut at the front.

The turning cutter *C* is a broad-faced affair 1⅞ in long secured in a rectangular seat in the front wing of the box tool body. The turning tool for the flange

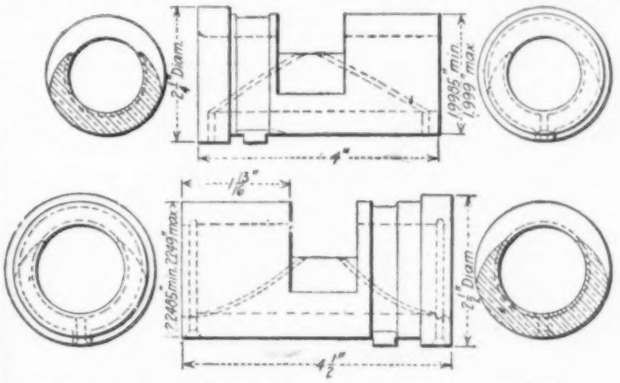


FIG. 2. ARMATURE-SHAFT BEARINGS MACHINED BY THE BOX TOOL

on the end of the work is a ⅜-in. square cutter inserted at *D* at an angle to give facility of adjustment. The facing cutter for the extreme end of the work is near the rear end of the chamber in the box tool as at *E*.

The tool in Fig. 4 is a form of hollow-mill adapted for turning from ¼ in. up to 1 in. in diameter.

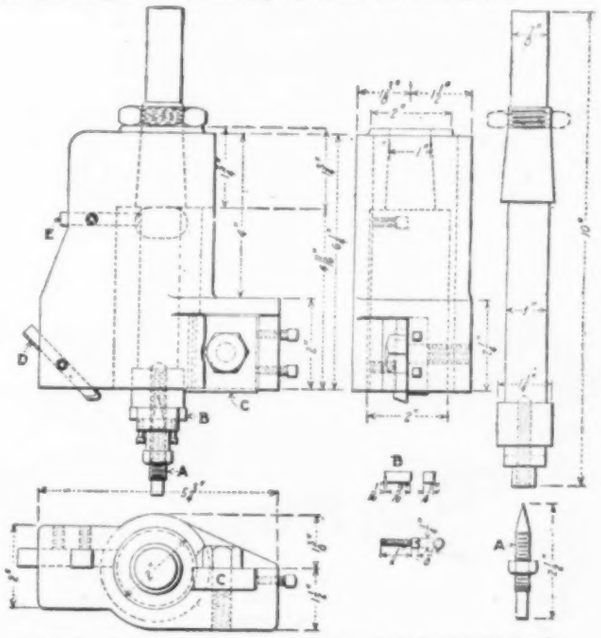


FIG. 3. DETAILS OF BOX TOOL AND BORING BAR

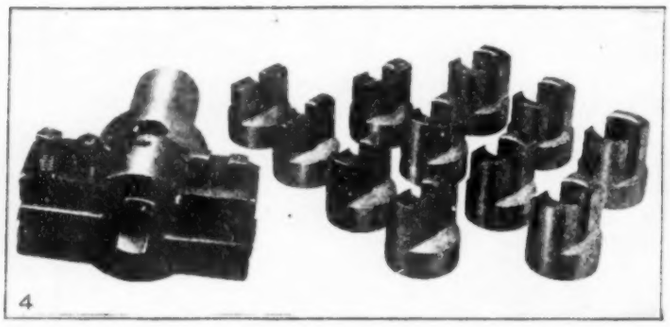


FIG. 4. ADJUSTABLE HOLLOW-MILL FOR BRASS WORK

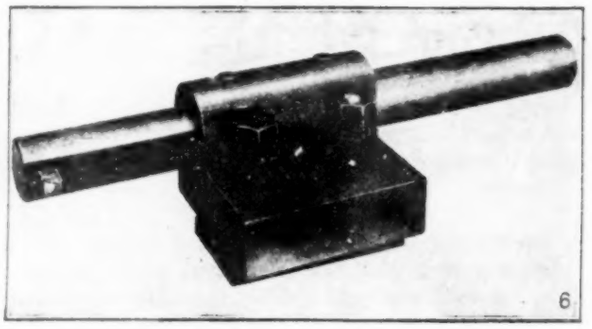


FIG. 6. BORING BAR FOR ROD BRASSES

The bushings with this tool are reproduced in the halftone, Fig. 4, and in the blueprint, Fig. 5. They are cut away at opposite sides to clear the cutters, but leaving about one-quarter of the circumference at each side for steadying the work under the action of the tools.

These bushings are made in various diameters of bore, and the set in Fig. 4 is arranged to cover by sixteenths all sizes between the limits mentioned above.

The cutters inserted at the sides of this tool are of Novo steel $\frac{5}{16}$ in. thick by 1 in. wide. They are

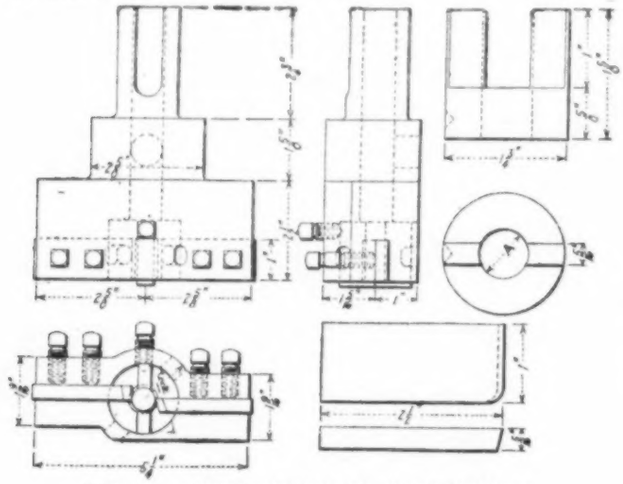


FIG. 5. CONSTRUCTION OF HOLLOW-MILL

each secured by two $\frac{3}{8}$-in. setscrews. It has been demonstrated that this form of tool stands up better on the class of work it is principally used for than the old style of hollow-mill, and it is said to have 80 per cent. longer life than the earlier type of mill.

A convenient form of boring bar for the engine lathe is shown in Fig. 6. This tool is used principally for such work as boring out rod brasses, and it may be set as required in the holder to give it any amount of extension necessary to pass through the work.

The bar itself is 2 in. in diameter and 24 in. long. It carries a boring tool of $\frac{3}{8}$-in. square steel, which may be shaped on the point to suit any class of material under operation.

The double bar holder in Fig. 7 is adapted for holding two bars as above, and these are placed $4\frac{1}{4}$ in. apart on center lines to carry tools for boring and turning such parts as brass slip rings for eccentrics. This ring as shown has an outside diameter of 18 in., an inside diameter of 16 in. and a width of 3 inches.

The section through the ring is 1 in., and heavy cuts and feeds are possible with the stiff bars in finishing the outside and inside surfaces. The brass casting is made in the form of a drum about 12 or 15 in. long so that it may be gripped in the lathe chuck by one end and one ring after another bored and turned and cut off to width.

Both boring-tool holders, the single and the double, are neatly proportioned, giving a bearing length for the bars equal to three and a half times the diameter. The bars are secured by headless screws, as are the boring and turning cutters, so that all surfaces are for the greater part entirely free of projecting screw heads.

A Shaping-Machine Tool

A tool for various classes of operations on the shaping machine is shown in Fig. 8. This tool is made primarily for such work as the shaping of brasses and for gasoline motors.

The brasses are shaped out with a lip on the upper one and a corresponding seat in the lower one. The tool is adjustable to give any desired offset between the ends of the cutting tools, and in the setting shown the center tool is set about $\frac{1}{4}$ in. out from the two

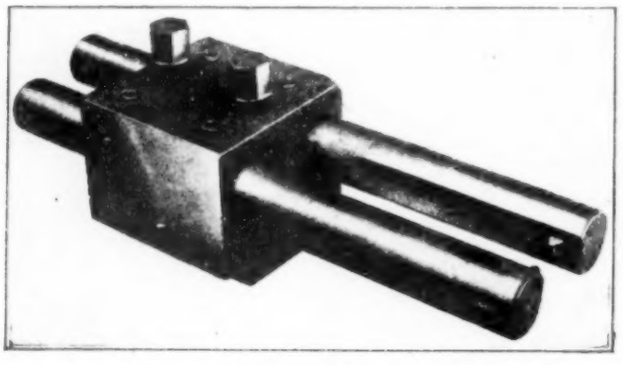


FIG. 7. DOUBLE BORING BAR FOR MACHINING ECCENTRIC SLIP RINGS

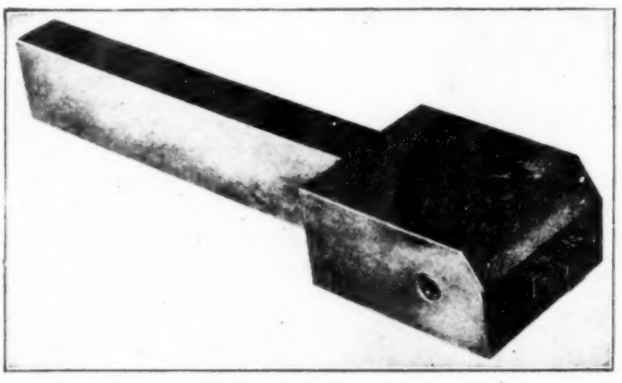


FIG. 8. ADJUSTABLE SHAPING TOOL FOR MOTOR-CAR BRASSES

outer tools. This setting is as the tools would be placed for shaping the work referred to, and with such a job in the shaping machine the tool could be fed in from one side to surface off the brass, leaving the shoulder or lip of the desired height and thickness, and then moved across to the opposite side and, without readjustment of any part of the machine, fed across that side to bring the face and lip into conformity with the side already completed.

The three tools are held not only by screws tapped into the top of the holder, but also secured from the side by an auxiliary screw at that point. The tools and appliances illustrated were made and are in use in the shops of the Southern Pacific Co., Sacramento, Calif.

Johnson Interests Mrs. Machinist

BY JOHN R. GODFREY

Most large firms have a convention to tell their salesmen what a fine product they make—they sell the idea of quality to the salesmen to pass on to the customers. This tells of a plan to sell the good points of the product to the men in the shop and to their wives as well. It's a new angle that seems to have real possibilities.

I'D BEEN vacationing a few days just to see if fish would still bite at old-fashioned grasshoppers or whether you had to dress 'em up a la mode or en casserole to get a real live pickerel out of the old pond. And the first thing I found on my desk when I got back was an invite from old man Johnson that read:

> The Johnson & Brown Co. invite you to the shop on July 19, 1919, at 8 p.m. to get acquainted with the plant, the work and incidentally the "old man." No speeches, booze or bunk—but a little get-together that we hope you'll enjoy.

On the other side was this:

> To the families of our men:
>
> We want to show you what we make—what good workers your husbands, sons and other girls' brothers are. We want you to appreciate them as much as we do—as much as they deserve.
>
> THE OLD MAN.

I'd hardly got this read and only half digested, when Johnson called me on the phone.

"Why in blazes didn't you come to my party the other night? Out of town, fishin'?—Well that's a good alibi if true, but you've got to prove it. Come and see me this P.M.—I'm bustin' to talk to you."

So after I'd gone over the mail—skimmed through the *A. M.*—to see whether Harry Senior or someone else had tanned my hide while I'd been gone, and stowed away about seventeen cents worth of fodder that cost sixty, I dropped into Johnson's so he could let off steam. Then, too, I was curious to know how his party came off.

He was all primed when I went in and couldn't talk fast enough to suit either of us.

"You know, Godfrey, I told you I had been thinking about the old shop and how we all knew what was going on. Then I remembered how the wife used to be interested in the shop, how she asked questions about the machines she saw through the windows, and quite forgave me for getting my face and hands dirty after the boss took her through the shop one afternoon.

"Then I wondered how many of the women folk of the men in our shop knew a derned thing about the kind of work the men did. Never had a chance to see. So I argued to myself that if I could show the women what really fine work their men did, it might boost the man's stock up to par when compared with the bank clerk next door and his clean-collar job. So I sent out the invites and waited with fear and trembling.

"No, they didn't all come, but we had a good-sized party, minus the address of welcome and the usual hot air. Mrs. Johnson and the girls helped out, and, believe me, John R., they're *some* mixers. They were comparing sponge-cake recipes, and embroidery patterns for things you don't talk about, with the girls in the punch-press room and the porter's wife inside of twenty minutes. There wasn't any ice to melt and they helped point out some of the good things about the motor and how well the work has to be done.

"I staged an exhibition in the show room that gave even a greenhorn a pretty good idea of the innards of the animal and the way it worked. I put signs showing the limits on the fine parts and had the men show just how small a half-thousandth is. Measured tissue paper and hair from little girls' heads and all the usual stunts.

"I didn't mean to say anything—intending to let it soak in by itself, but the crowd yelled a lung loose for 'speech'—and so I told 'em a few things I had on my mind. Here's what the stenog's pothooks says I said—I'm taking her word for it, omitting the Ladies-and Gentlemen stuff.

" 'I wanted you to come and see what kind of work your men were doing, to see what fine, accurate work it was and to appreciate the skill it requires. Unless you do know this, you might think only of the grimy hands and dirty overalls. You might even think that your husband or father or brother wasn't as smart as the nearby neighbor who keeps clean at his job in the bank or behind the ribbon counter.

" 'Now, you know that isn't so. The work your men do here requires more skill and more training than any clean-collar job I know of. These machines helped to win the war. They help civilization in all parts of the world. But they must be well made, and here is where the skill of your men comes in.

" 'We want you to appreciate your men, to keep them cheerful, to help them to be enthusiastic about the shop and its work. We want them to feel just the same pride in this work that we used to in the old days when the shop was small. Times have changed but I want you to help us get back the real family feeling of the old shop. We can't do it without your help—but I feel sure we're going to get that from now on.

" 'When your neighbor talks airily of her husband's job in the bank, you'll know that it doesn't take half as much brains to punch an adding machine, to handle other people's coin and to keep creases in their trousers, as it does to make the pistons and crankshafts and connecting-rods on our motor. And after he gets the grime off, which he can do here in the shop if he wants to take time, its dollars to doughnuts your John

is cleverer and better in every way than the other chap. Of course we have to have bank clerks just as we have to have policemen and boys on the elevator, but it isn't half so much a real man's job as actually making something useful. To take rough iron castings and steel forgings and, by real knowledge and skill, turn them into a machine that helps thousands of people is a real job, and you ought to be proud of the men who can do it.'

"Perhaps you think I put it on too thick, Godfrey, but I'm getting more enthusiastic myself, the more I think of it.. And there's a mighty healthy atmosphere in the shop these days.

"I simply swiped the idea from the salesmen's conventions we've been holding every year. There we pay all the expenses of having the men come in off the road so we can enthuse them with the quality of our product. If it's a good idea to sell the product to the salesmen, why not to the men who actually build the machines? And then I went it one better by telling the men's wives what fine pickers they were when it came to husbands.

"The boys in the shop are doing splendidly and we're trying to plan out some simple way in which we can get together and talk over all sorts of shop problems—just as we used to in the old shop. Perhaps I'll have something new to tell you later. But believe me, that little exhibition helped us get closer to the men and their families than anything I know of. I don't expect any millenium or that everybody will fall on each other's neck and be happy, but its stepping along in the right direction—unless all signs fail."

Thread Cutting in a Boring Mill

By M. E. Hoag

The lathe faceplate shown in Fig. 1 was made by the W. A. Jones Foundry and Machine Co. of Chicago. It weighs 6¼ tons, is 96 in. in diameter, 13½ in. wide, and is bored and threaded to take the lathe spindle nose, which is 14 in. in diameter with a U. S. standard thread of 1 in. pitch.

The turning and facing of this faceplate was handled on a boring mill and involved no unusual operations. The threading of the hole was, however, a different proposition, as there was no feed on the mill that corresponded to it.

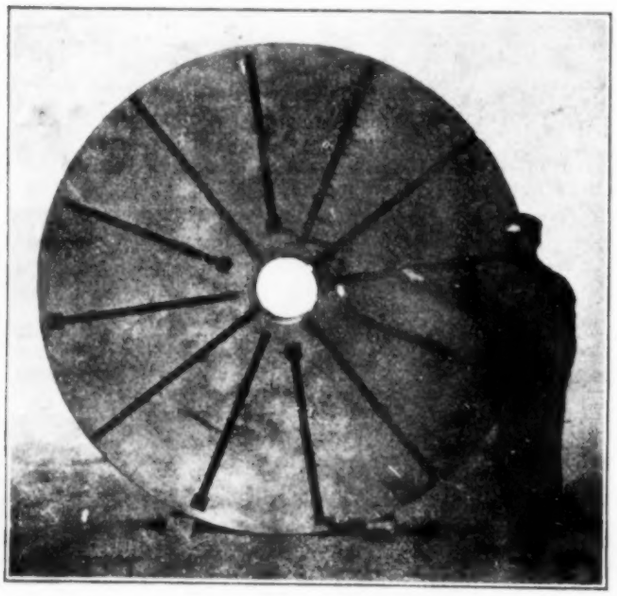


FIG. 1. LATHE FACEPLATE TO BE THREADED

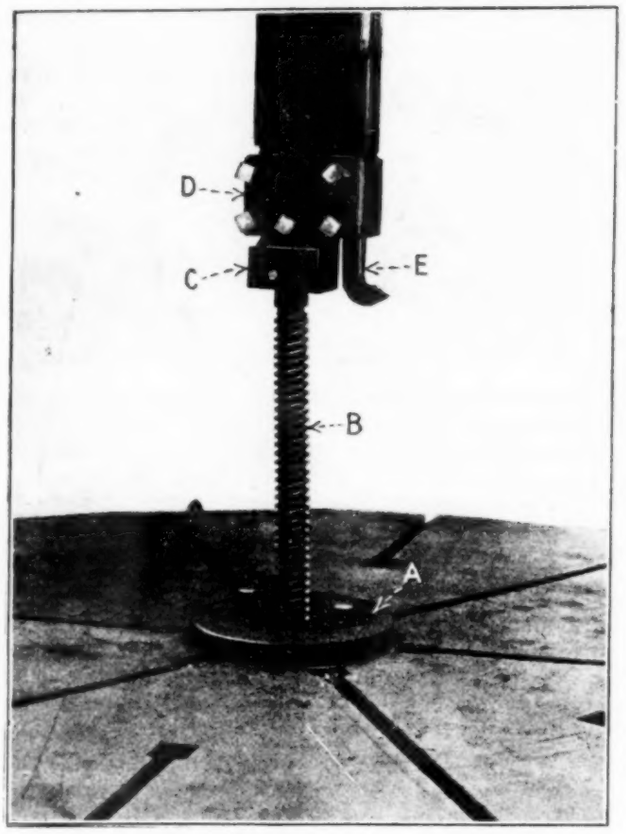


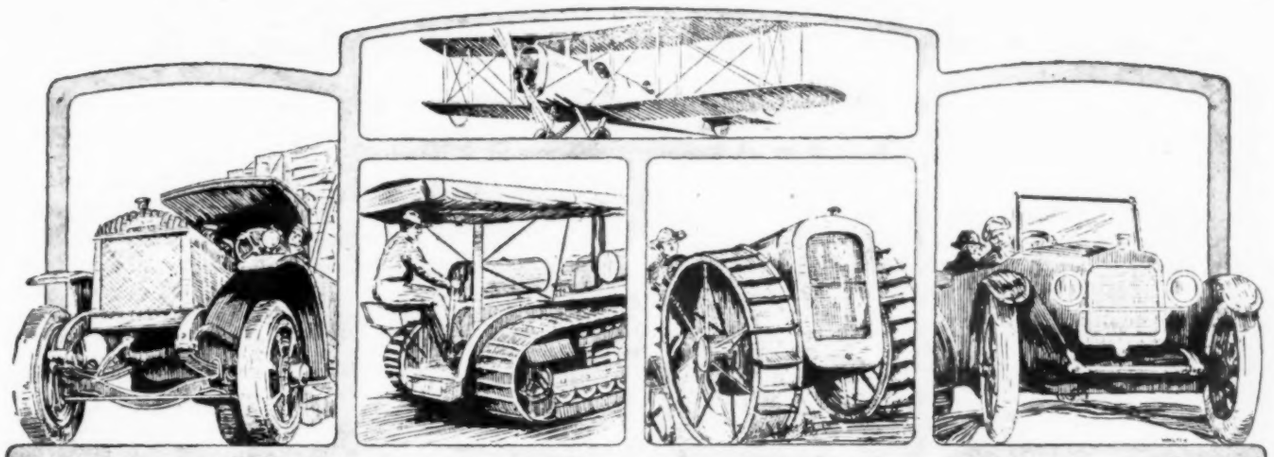
FIG. 2. RIG FOR THREADING IN A BORING MILL

The superintendent of the machine shop worked out a simple solution of this problem as shown in Fig. 2. The bushing *A* was made to fit the opening in the faceplate of the boring mill, and bolted to it as shown. This bushing was bored and threaded to take the screw *B* which was made with a double thread. The upper end of this screw has a flat tongue milled on it, which fits a slot in the holder *C*, and the latter in turn is fastened in the tool head *D*. A half-inch hole in the flat end of the screw *B* receives a half-inch steel pin which also passes through the slots in the side of the holder *C*. These slots permit the feeding of the tool *E* into the work without disarranging the screw *B*. While cutting the thread in the faceplate, the up and down feeds were disengaged, thus leaving the head free to work up and down with the screw *B*. The turning of the boring mill and bushing *A* draws the screw *B*, holder *C*, tool head and threading tool *E*, down through the work. In this way a very accurate piece of work was made.

Erratum

In an article entitled "Setting Diamonds for Wheel Dressing," by G. E. Woodley, published on page 407 there is an obvious error or oversight. In the first paragraph under the subheading "Time Required to Set Diamonds," the third sentence states that "no turning is required; simply drill a $\frac{3}{16}$-in. hole."

This should read "a $\frac{9}{16}$-in. hole, ½ in. deep, is drilled in the end of the holder, and at the bottom of this hole a $\frac{3}{16}$-in. hole is continued ½ in. farther." This makes room for the cage containing the diamond, and the smaller hole holds the split ends of the $\frac{3}{16}$-in. wire from which the cage is made.



AUTOMOTIVE CONSTRUCTION

The Hispano-Suiza Airplane Engine—VI

By H. O. C. ISENBERG
Works manager, Wright-Martin Aircraft Corporation, New Brunswick (N. J.) Plant

The numerous operations that are necessary on the cylinders and cylinder block must be performed with unusual accuracy so that when assembled the spacing and alignment will be within very close limits. This is particularly necessary for the operation of grinding the cylinder bores as the wall thickness must be kept virtually the same at all places. Detail drawings of the parts are given and many of the operations together with some of the tools used are described.

THE cylinders or sleeves, Fig. 68, are steel forgings and are received at the plant in a rough-machined condition. They are finish-bored in a Gisholt lathe, Fig. 69, and are held in a three-jaw chuck having special long jaws. The operation includes, besides boring, recessing at the top for clearance for the grinding wheel, facing and turning the flange and chamfering the mouth of the bore. The boring bar is held in a steadyrest *A* mounted on and spanning the carriage, one of the feet being visible at *B*. The steadyrest bushing has keyways at opposite sides to permit the passage of the cutting tools at the ends of the several bars used. The carriage is kept in the position shown in the illustration and the feed is by traverse of the turret slide. In boring the cylinders, from 0.013 to 0.020 in. is left in the diameter for grinding.

The tolerances are, for depth of recess, 0.005 in.; outside of flange, 0.005 in.; depth, 0.004 in., and for flatness at the top, 0.0015 in. The gages used are pin "go" and "not go" for the bore, pin for depth of recess, snap for outside of flange, flush-pin for depth and an indicator for squaring the top. No. 1 mineral lard oil is used as a coolant and the production is 20 per machine in 8 hours with one operator.

Turning and facing is done on a Jones & Lamson two-spindle flat-turret lathe, the operation and the tool set-up being shown in Fig. 70. The work is held by an air-operated mandrel of the button type and Stellite tools are used. The operation is such as is usually done in machines of this type and as there is nothing unusual about it no detailed description is necessary. Oakite is used as a coolant and the production is 40 per machine in 8 hours with one operator.

Cutting the thread is done in an engine lathe rigged

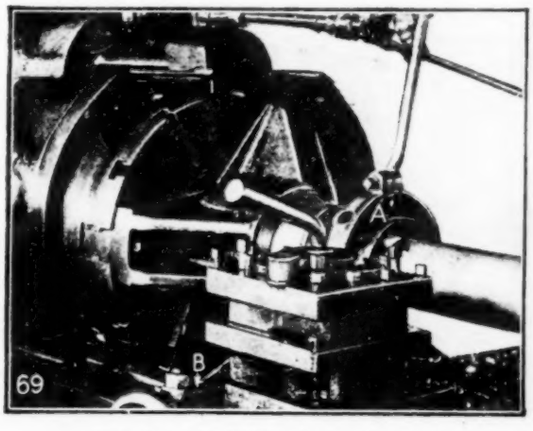


FIG. 69. BORING THE CYLINDERS

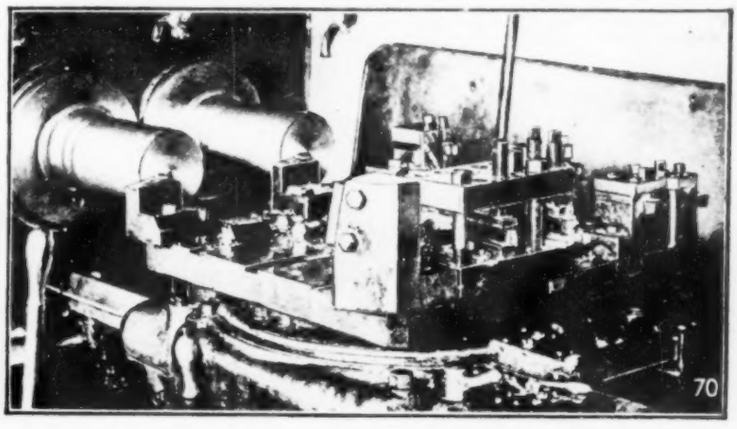


FIG. 70. TURNING AND FACING THE CYLINDERS

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up for the work as shown in Fig. 71, using a Modern self-opening die with the work held on an air-operated mandrel. The lead screw is used to give the proper lead to the thread, thus making it entirely independent of the lead of the die. The thread is 1.5 mm. in pitch and is completed in one cut. The gages used are female-thread gage and a lead gage with points 100 mm. apart. No. 1 mineral lard oil is used as a coolant and the production is 50 per machine in 8 hours with one operator.

The tops of the cylinders are ground 0.003 in. crowning on the outside, the purpose of which will be explained later. This is done in a grinding machine which was rigged up for the purpose.

The cylinder block, Fig. 72, is an aluminum-copper casting and, as may be seen in the illustration, it has numerous cored holes and passages, some of the latter being quite intricate, and all calling for extremely accurate core setting on the part of the foundry.

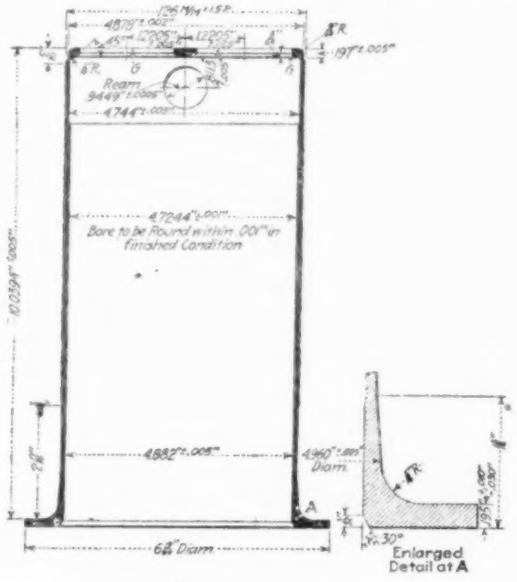
The first machine operation is to drill out the cored holes *A* in the water jacket with a 1½-in. drill. The block is mounted on a special angle plate having two pilots on its vertical face. These pilots enter the two end sleeve holes and support the block while the holes are being drilled. No jig is used and the fact that these holes so drilled are later used to determine the location of center lines speaks volumes for the accuracy of core setting.

After drilling, the block is passed to a surface plate where it is leveled up by jackscrews and center lines scribed on the top and bottom to be used as guides for setting in the Pratt & Whitney duplex milling machine, where these surfaces are finished. Here two blocks are mounted in fixtures set tandem so that one block may be loaded or unloaded while the other one is being milled.

In setting the block in the milling machine the gage *A*, Fig. 73, is used to indicate the position by the center lines before referred to. The bottom of the gage rests on and can be slid along planed surfaces on the base of the fixture and the block is raised or lowered by jackscrews until the center lines coincide with the beveled top edge of the gage.

At the top of the fixture are two slotted horns *B* into which the bar gage *C* is dropped. This gage is used to set the block parallel with the ways of the milling machine. The distance from the top to the bottom of the block is held within a tolerance of 0.005 in., "go" and "not go" gages being used. The production is 26 per machine in 8 hours.

The next operation is drilling the holes for bolting



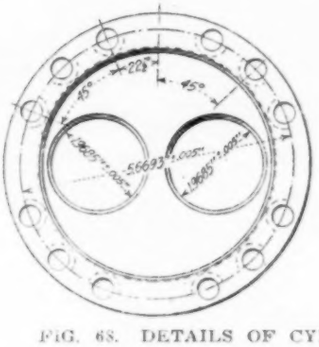


FIG. 68. DETAILS OF CYLINDER

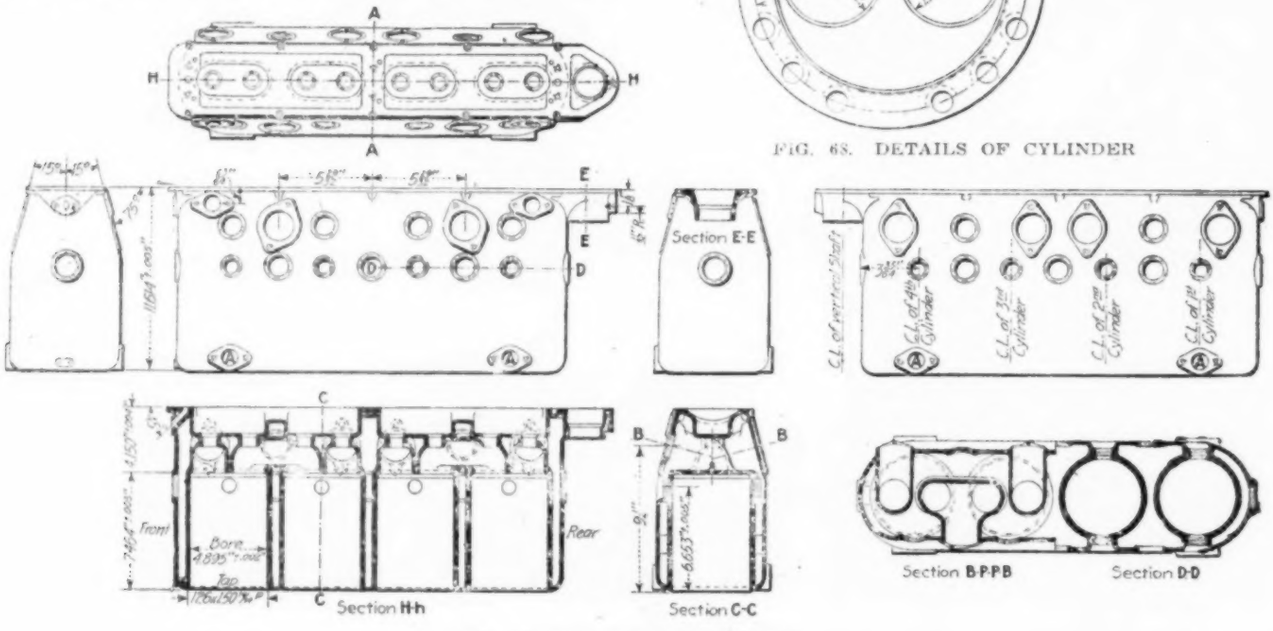


FIG. 72. THE CYLINDER BLOCK

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on the camshaft cover and two dowel holes. This is done in a Baush multiple-spindle drilling machine as shown in Fig. 74. The block is held in a box jig and as some of the holes are closer together than the spindles can be set, two operations are necessary to complete the drilling, the drills being so arranged that the block is turned end for end for the second operation. The two dowel holes are reamed by hand before removing the block from the jig, the drill bushings being removed and reaming bushings inserted. Two operators are required and the production is 52 per machine in 8 hours.

After the drilling has been completed the block is straddle-milled in a knee-type milling machine to face off the pads for the water holes. The block is located in a fixture by the dowel holes referred to in the previous operation and two large straddle mills are used. No gages are used and the production is 55 per machine in 8 hours with one operator.

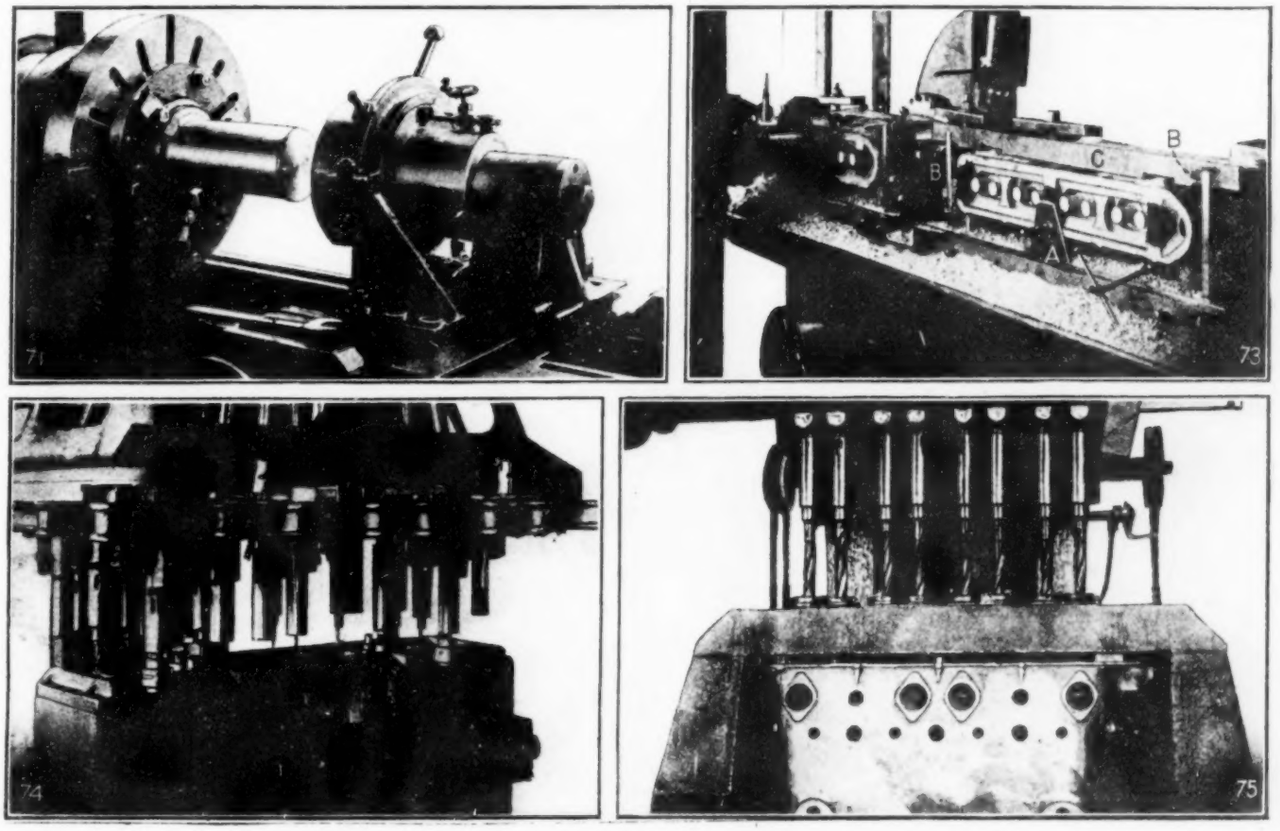
In drilling the eight holes for the valve guides, the block is mounted in a jig that is built into a Moline eight-spindle drilling machine as shown in Fig. 75, and is forced up against the under surface of the jig plate by wedges below. Location in the jig is by the dowel holes in the top flange. The valve-guide holes are afterward faced, finish-bored and tapped.

Boring the four holes for the cylinders or sleeves is done on a Foote-Burt four-spindle boring machine as shown in Fig. 76. The work is held in a jig that is permanently located on the machine and is again located by the dowel holes as in previous operations. In order to save repetition it may be stated that these same dowel holes are used for locating the work wherever possible in all the future operations on the block.

Two operations, roughing and finishing, are carried out and in the latter the work is held to a tolerance of 0.002 in. One of the boring heads is shown in Fig. 77 at *A*. The cutter extending across the face is for rough-facing the bottom of the hole. This is to be finished in a further operation that will be described later. The coolant used is a mixture of 20 per cent. mineral lard oil and 80 per cent. kerosene. One cut is taken for each operation at a speed of 85 ft. per min. with a feed of 0.020 per revolution. "Go" and "not go" pin gages are used for the diameter and a flush-pin gage for the depth in which the tolerance is 0.003 in. The production is 35 in. per machine in 8 hours with one operator.

Following this operation and between other principal operations about to be described various parts of the block are milled, drilled and tapped, but as these include only such work as is done in everyday machine-shop practice, description of them is omitted as being of no particular interest.

Milling the pads for the oil pressure pipe is done on a Cincinnati knee-type milling machine provided with a special attachment for driving two cutters at once as may be seen in Fig. 78. The block is located



FIGS. 71, 73, 74 AND 75. OPERATIONS ON CYLINDERS AND CYLINDER BLOCKS

Fig. 71—Cutting the thread on a cylinder. Fig. 73—Milling the top and bottom of a cylinder block. Fig. 74—Drilling for the camshaft cover. Fig. 75—Drilling for the valve guides.

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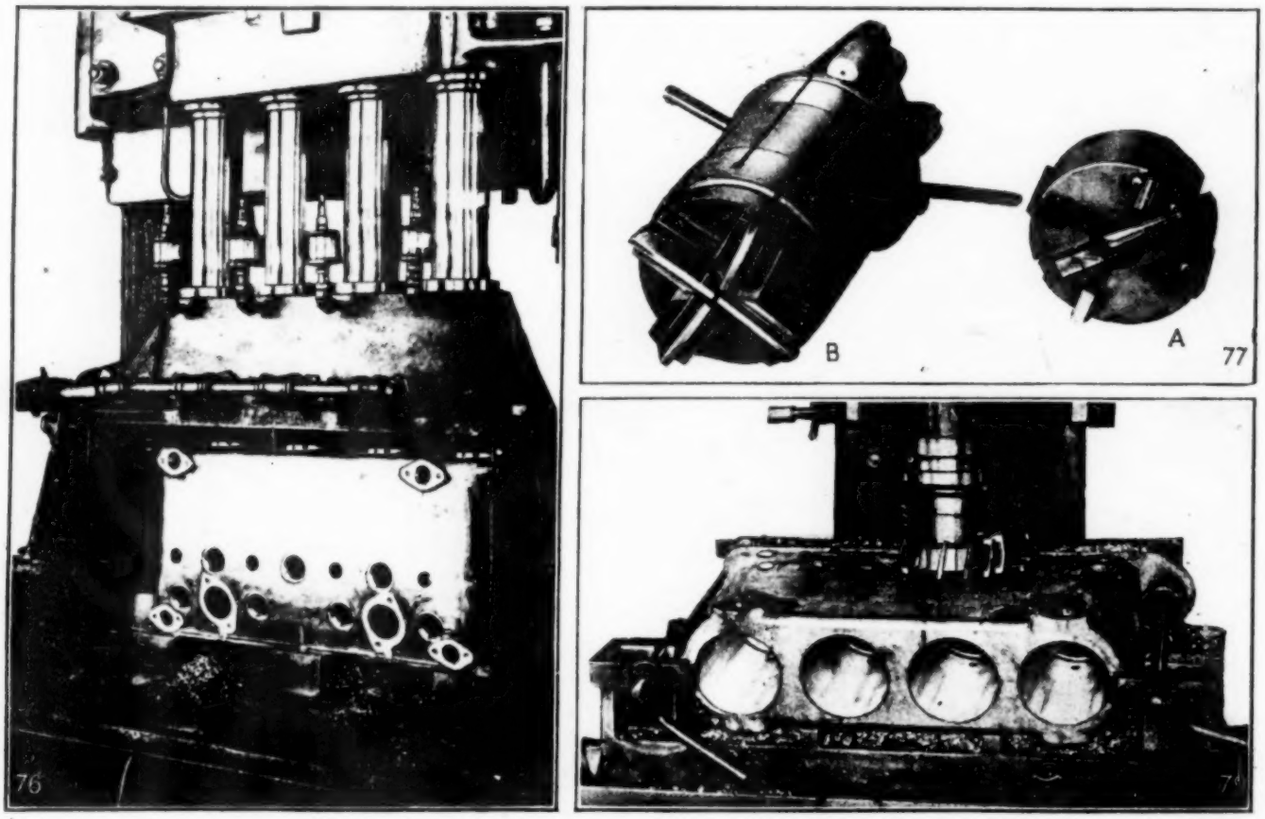
by short pilots that enter the first and third cylinder holes. One gage for position and two for depth are used and the tolerance is 0.010. The operation is completed in one cut in which no coolant is used. The production is 100 per machine in 8 hours with one operator.

Milling the pads for the intake and exhaust is done in a Cincinnati vertical milling machine with the work held in a fixture to present the work at the proper angle. Fig. 79 shows the operation. The job is finished in one cut which is made without coolant and the production is 50 per machine in 8 hours with one operator. The gage used for this operation is shown in Fig. 80. The long bar *A* is provided with pins that fit into the locating dowel holes before referred to. On its upper surface are two blocks *B* provided with slots in which the gage *C* slides. When the crossbar *D* contacts with the milled surface of the pad the rear end of the gage, which is of the flush-pin type, must come flush with the back surface of the block. The tolerance is 0.003 in.

Rough-boring the valve parts is done in an eight-spindle drilling machine. The boring bars are provided with long pilots that extend through cored holes in the block and are guided by bushings in the base of the fixture.

Tapping the cylinder holes, Fig. 81, is done in a Colburn vertical drilling machine provided with a lead-screw that is cut on the upper part of the spindle so that the correct lead of the finished thread will be independent of the lead on the tap. A geometric collapsible tap 126 mm. in diameter and 1.5 mm. in pitch is used and the hole is tapped the full depth, 8¼ in. The tap is run at 85 ft. per min. and Oakite is used as a coolant. One operator runs two machines and the production is 14 blocks or 56 holes per machine in 8 hours.

During the operation the block is held in a fixture in which provision is made for longitudinal travel and operated by rack and pinion. The position for each hole is located by an index pin operated by a treadle. Two of the pockets in which the index pin fits may be seen at *A*.



FIGS. 76, 77 AND 79. BORING CYLINDER HOLES, BORING TOOLS AND A MILLING OPERATION
Fig. 76—Boring cylinder holes. Fig. 77—Boring and facing tools. Fig. 79—Milling intake pads.

Upon completion of the foregoing operations on the cylinder block it is tested at 40-lb. hydraulic pressure as shown in Fig. 82. The fixture is arranged to revolve on trunnions so that all parts of the exterior of the block may be readily examined. All outlet holes are made water-tight by blank rubber gaskets forced against them by the handscrews shown in the illustration. Leaky spots may be soldered up or drilled out, tapped and plugged, according to their extent and location.

Facing Bottoms of Cylinder Holes

The final operation on the cylinder block before assembling the cylinders in place is to finish-face the bottoms of the holes.

The operation is shown in Fig. 83 and a close-up view of the cutter and the fixture for guiding it may be

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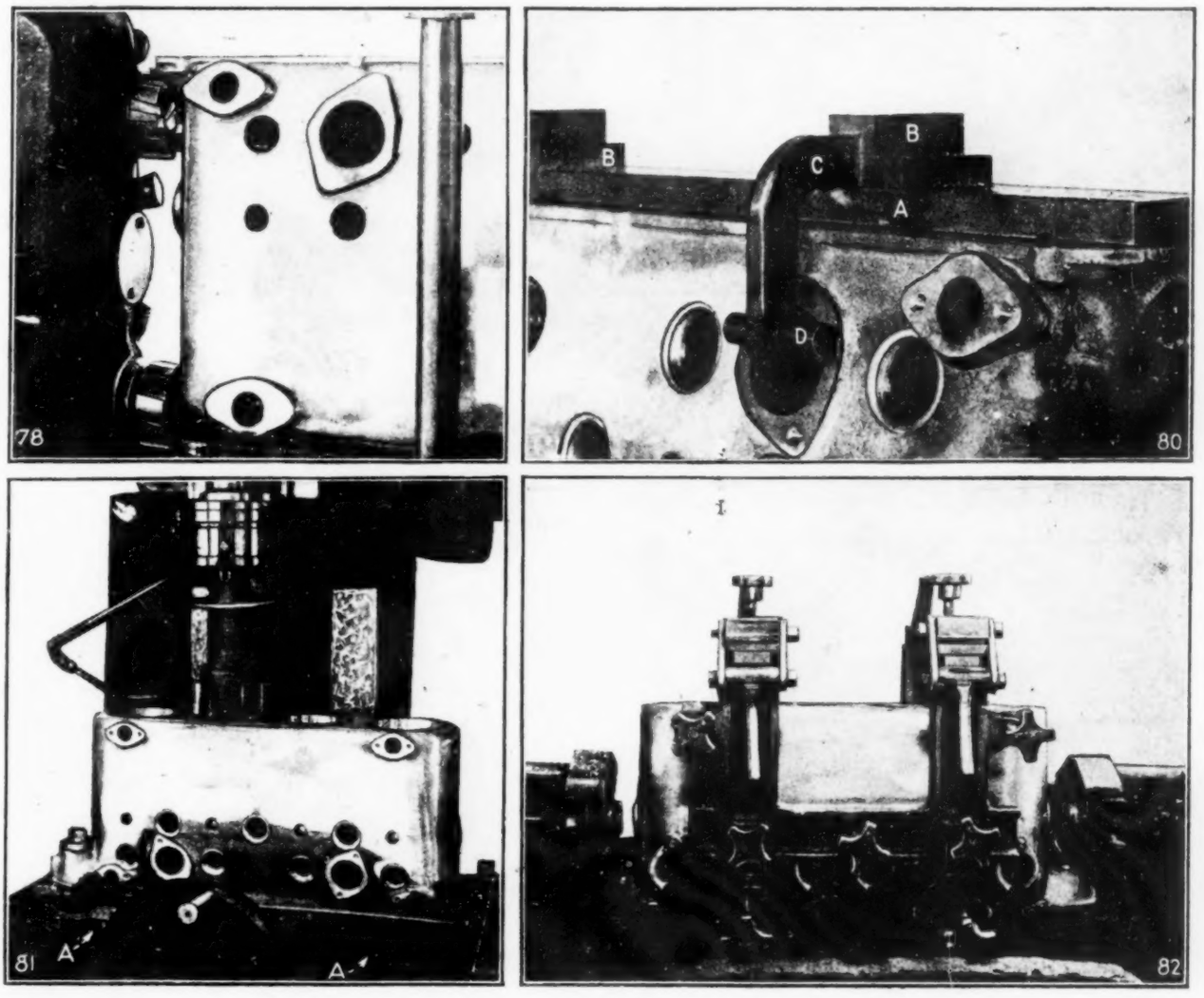
seen at *B*, Fig. 77. The fixture is screwed into the hole by the fork *A*, Fig. 83, which grips the pins *B*, and when it has reached the proper depth the lower faces of the pins *C* contact with the top of the cylinder block. The fork is then removed and the spindle of the drilling machine attached to the cutter shank. A wrench applied to the pinion shank *A*, Fig. 84, revolves the pinion and the gear *B*. This acting on a screw in the interior draws together two conical blocks that spread the split bushing until it fits the tapped hole snugly and positions the fixture centrally. Power being applied, it only remains to feed the spindle downward to the cut.

Facing the bottoms of these holes is a very particular job as the tolerance for depth is only 0.003 in. and the bottoms must be as near flat as it is possible to get them. A mixture of mineral lard oil and kerosene is used as a coolant and the production is 18 blocks per machine in 8 hours with one operator.

In assembling the cylinders in place, the cylinder block is clamped to a stand allowing free passage all around it. A cylinder is coated lightly on the top and threads with prussian blue and then screwed into the cylinder block. It requires about 120 turns to screw in the cylinder and in order to save the time necessary to do this by hand a Cleveland air motor, Fig. 85, suspended from a pulley and balanced by weights, is used. An internal expanding chuck *A*, Fig. 86, is inserted in the cylinder and connected to the air motor by a taper shank. This chuck is arranged to expand by rotary motion given to the shank in either direction so that it can be used either for screwing in the cylinder or taking it out, though the grip is not strong enough to jam the threads should the fit be too tight. After the cylinder has been screwed in, the expanding chuck is removed and the clamp *B* attached. The pilot *C* enters the bore of the cylinder, the jaws *D* snap over the flange and are tightened by the screw *E*. The cylinder is then screwed in tightly by using a bar on top of the clamp between the lugs *G*. After screwing the cylinder in, it is removed, and the marking on the bottom of the hole made by the prussian blue examined.



FIGS. 78, 80, 81 AND 82. MILLING, GAGING, TAPPING AND TESTING

Fig. 78—Milling pads for oil pressure pipe. Fig. 80—Gaging intake and exhaust pads. Fig. 81—Tapping cylinder holes. Fig. 82—Hydraulic testing for leaks

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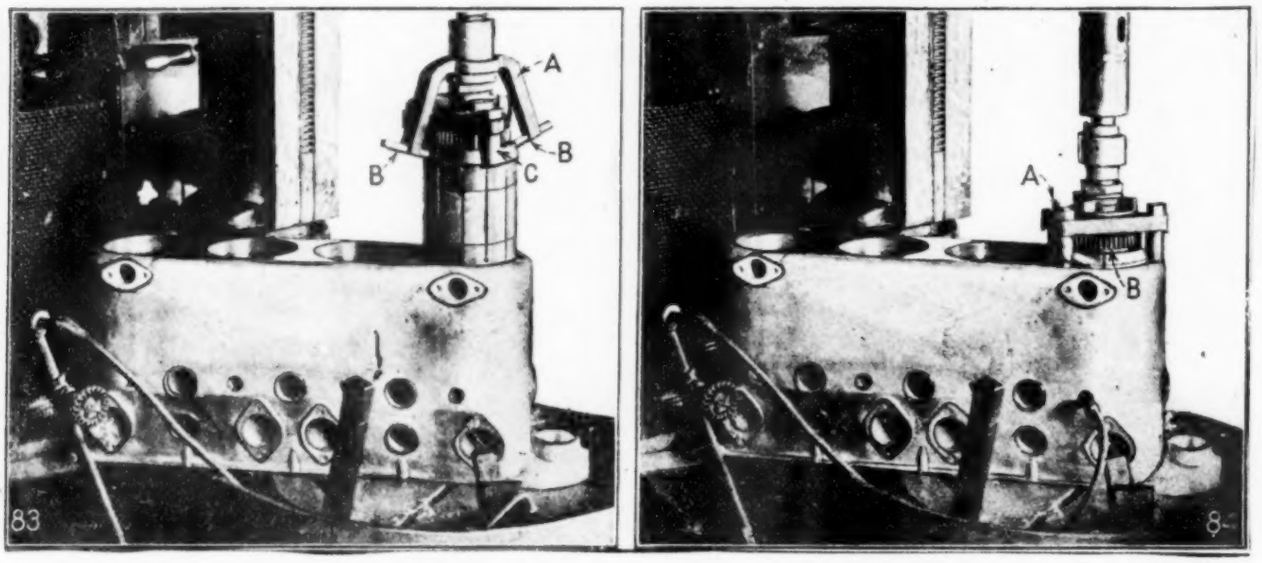


FIGS. 83 AND 84. FACING BOTTOMS OF CYLINDER HOLES

Any failure to show a 95-per cent. bearing at this point must be corrected by scraping.

This is a vital point because the valve ports are afterward bored through the top of the cylinder and the joint must be tight enough to prevent the escape of gases under high pressure from one part to another.

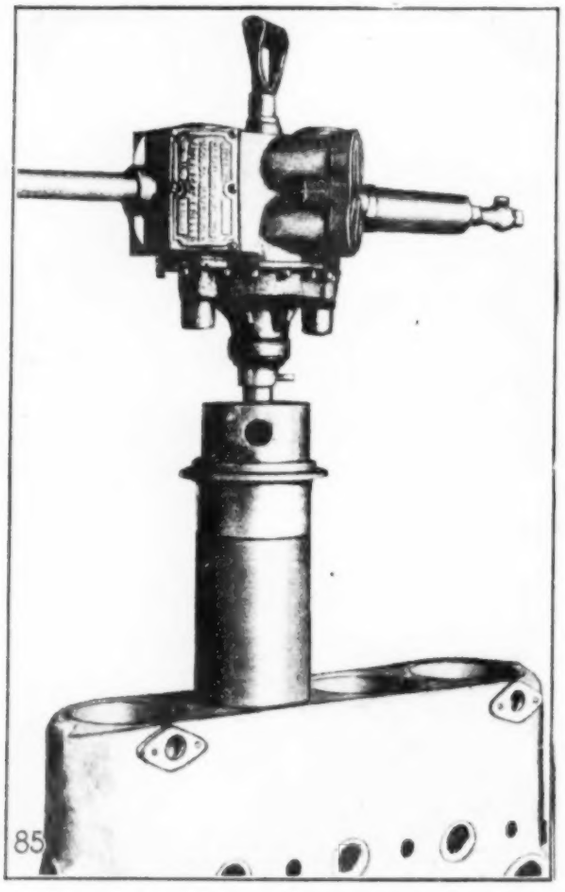
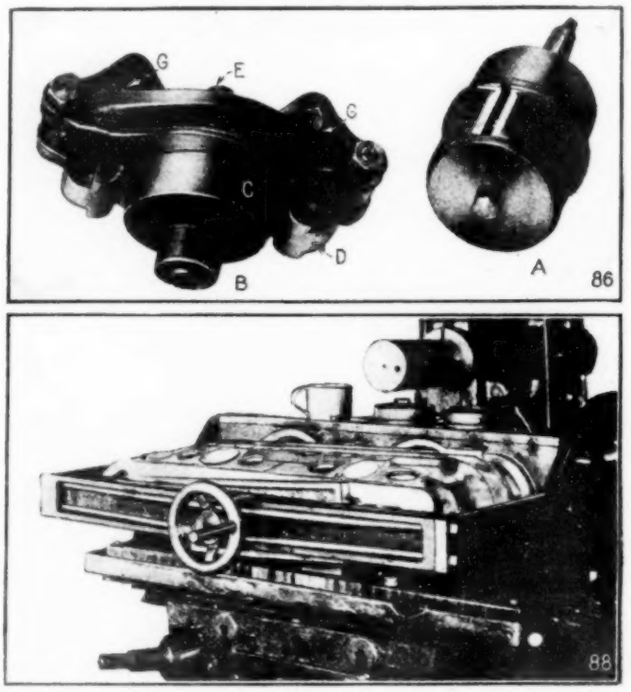


FIG. 85. SCREWING IN A CYLINDER

The adjacent edges of the ports are only about $\frac{3}{8}$ in. apart and to insure a thoroughly tight joint the top of the cylinder is crowned 0.003 in. by grinding. This crown flattens out almost entirely when the cylinder is forced home but naturally will have the closest contact in the center where the tightness of the joint must insure the least danger from leaking. The bearing between the threads on the cylinder and those in the hole must also be of a satisfactory character.

The center distance between the cylinders, Fig. 87, is too close to allow them all to be screwed into the block at one time without interference at the flanges



FIGS. 86 AND 88. TOOLS AND A MILLING OPERATION

Fig. 86—Chuck and clamp for screwing in cylinders. Fig. 88—Milling arcs on cylinder flanges

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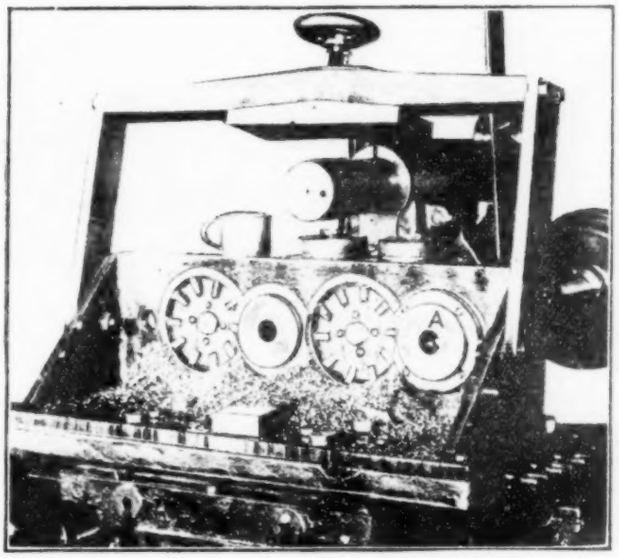

FIG. 89. SET-UP FOR MILLING ARCS ON CYLINDER FLANGES

so that cylinders Nos. 2 and 4 are fitted first and then removed. Nos. 1 and 3 are then fitted and left in permanently.

The block containing these two cylinders is then mounted on a Kempsmith milling machine, Fig. 88, provided with an attachment for driving two cutters

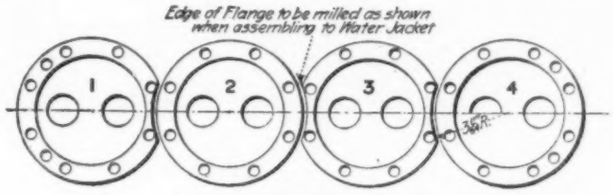

FIG. 87. PLANS SHOWING CYLINDER SPACINGS

simultaneously. Fig. 89 shows the arrangement of the cutters and the fixture. Here two segments are cut, one from each side of No. 3 cylinder and one segment from No. 1 cylinder.

The block is located by the pilots *A* which enter cylinder holes Nos. 2 and 4. With these segments cut from the flanges, cylinders Nos. 2 and 4 can be screwed in place without interference. No gages are used, dependence being placed on the correct size of the cutters. The coolant used is No. 1 mineral lard oil and the production with one operator is 65 per machine in 8 hours. Drilling the cylinder flanges for attaching them to the crank case is done in a Baush multiple-spindle drilling machine with a jig plate as shown in Fig. 90. The two end cylinders have 10 holes and the intermediate ones eight holes. As will be seen in the illustration the drills are grouped for drilling one end cylinder and the intermediate cylinder nearest the other end. By changing the block end for end the other two cylinders can be drilled, after which the extra holes in the end cylinders, which are dowel holes, are reamed. A plug gage is used for gaging these holes. The feed is by hand and the production is 60 blocks per machine in 8 hours.

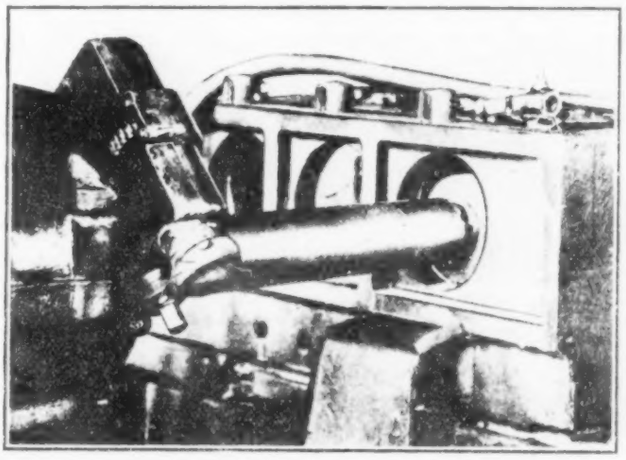

FIG. 94. GRINDING THE CYLINDERS

The bolt holes in the cylinder flanges must be back-faced for the bolt heads. In ordinary shop practice this would call for the use of a back-facing tool which is necessarily slow and tedious. However, this operation is quickly performed by the ingenious device shown in Fig. 91, which is of French origin. The cutting tool *A* with a short square shank *B* has a bearing in

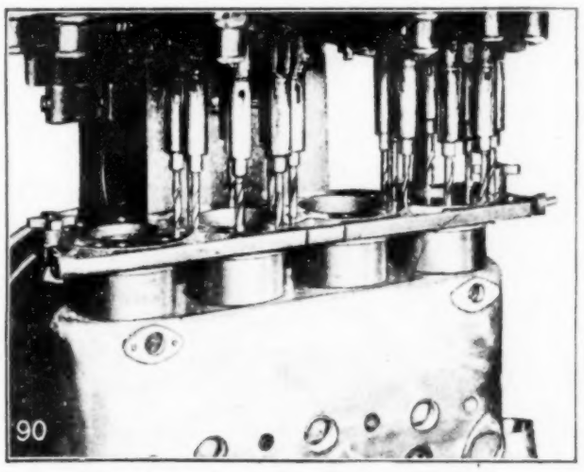

FIG. 90. DRILLING THE FLANGES

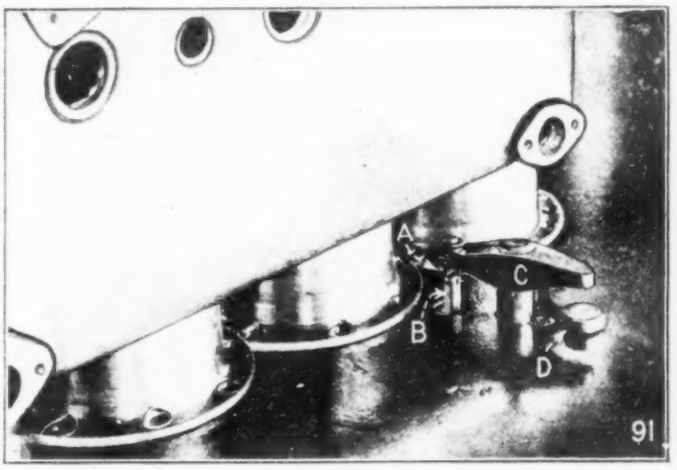

FIG. 91. BACK-FACING THE BOLT HOLES

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the part *C* and with which it is raised or lowered by a lever beneath the table. Under the table and in line with the axis of the cutter is a rotating vertical shaft with a square hole in its upper end.

In operation the cutter is raised until the end of the shank is above the table and the work. The block of cylinders is then placed so that the hole to be backfaced is under and in line with the cutter. The device is then lowered and the cutter shank passes through the hole in the work and enters the square hole in the rotating shaft. Rotary motion is thus imparted to the cutter and it is only necessary to further lower the device to obtain the required depth of cut. This is

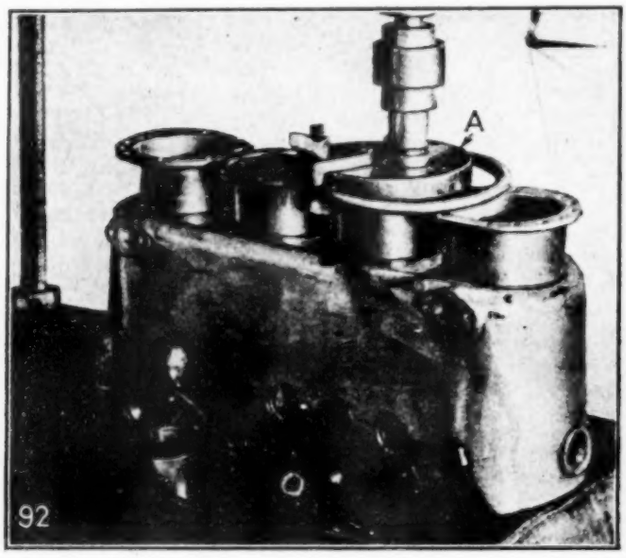


FIG. 92. TREPANNING THE VALVE PORTS

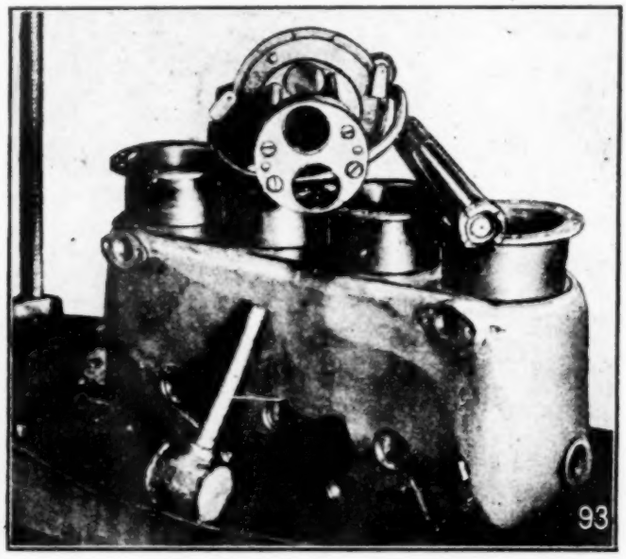


FIG. 93. THE JIG AND THE TREPANNING TOOL

determined by the block *D* which acts as a stop to limit the downward motion.

The valve ports which have been bored in the cylinder block in a previous operation are now covered up by the closed end of the cylinder which must be opened up to make connection with them. This is done by trepanning and the operation is illustrated in Fig. 92. The jig *A* fits the cylinder and is located by a pin in the under side of the flange, entering one of the bolt holes in the cylinders. Fig. 93 shows the jig and the trepanning tool on top of the work. The jig is provided with a swinging bail to facilitate handling.

The operation is one of roughing and the holes are afterward finish-bored in a multiple-spindle drilling machine using cutter bars with long pilots that extend through the work and into a jig at the base of the machine. In this operation both the holes in the cylinder and those matching them in the block are bored. In the rough-boring operation the tolerance is 0.005 in. and "go" and "not go" plug gages are used. Oakite is used as a coolant and the production is 65 blocks per machine in 8 hours with one operator.

The flange surfaces of the four cylinders as assembled in the cylinder block are naturally more or less irregular, due to their original slight variation in length and the variation in the depth of the holes into which they are screwed. These surfaces must now be ground to present as perfect a plane as possible, not only that they may make a tight joint with the lapped edges of the upper crank case to which they are bolted, with no intervening gasket, but to present a flat-clamping surface in the grinding machine when grinding their bores.

The flanges are ground in a Pratt & Whitney vertical grinding machine using a cupped wheel and upon completion of the operation the cylinder block has a light cut taken off the top by milling so that it will be parallel with the cylinder flanges.

In grinding the cylinder bores, Fig. 94, the entire block is mounted in a fixture on a Heald cylinder-grinding machine and located by dowel holes in the top. Centering the bore is done entirely by sound of the abrasive wheel as it touches the cylinder walls, the fixture being adjusted until the wheel touches the cylinder all around. It is necessary to try this out on each cylinder in the block so that any error in the relative position of two or more cylinders may be averaged up among the lot. There is, however, a limit to this procedure as the walls of the cylinders are only 0.079 in. thick and it is important to keep this thickness as uniform as possible to avoid distortion by heat of the engine when in operation. No departure is allowed in the alignment of the cylinders, though some little latitude is permissible in the spacing, as a slight variation in this respect is compensated for in the side play of the connecting-rods on the piston pins.

Grinding is done with a 4-in. x $\frac{3}{4}$-in. 38-36 I Alundum wheel running at 6400 r.p.m., using one pint each of White & Bagley compound and No. 1 mineral lard oil to 10 gal. of water as a lubricant. The amount to be removed by grinding is from 0.013 in. to 0.020 inch

In roughing out the hole the spindle makes 40 eccentric turns per minute and the feed is $\frac{1}{4}$ in. per turn. In the finish-grinding the eccentric turns are 80 per min. with a feed of $\frac{1}{32}$ in. per turn.

Inside micrometers are used for gaging, and the tolerance is 0.001 in. The production is two blocks or eight holes per machine in 8 hours with one operator.

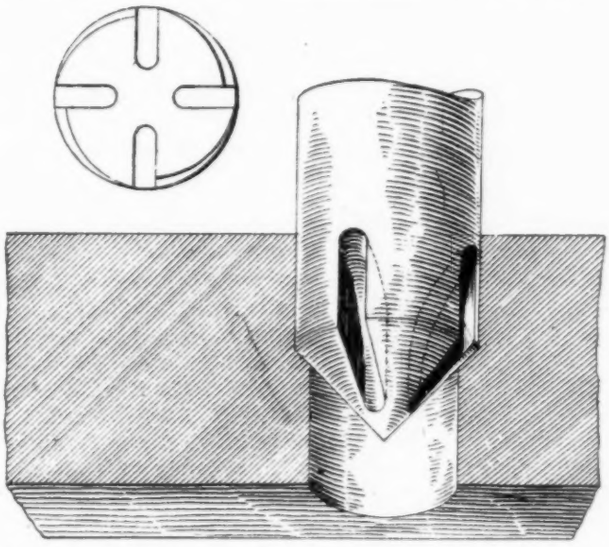
IDEAS FROM PRACTICAL MEN

Tool for Drilling Out Cored Holes

By S. C. Royal

In drilling cored holes to finish size, difficulty is often experienced from the chattering and snagging of the drill on the rough surface, resulting in a hole that is neither round nor accurate.

The tool shown in the sketch will overcome this difficulty and produce a hole with a good finish, free from



TOOL FOR DRILLING OUT CORED HOLES

chatter marks and true to size. It consists only of a rod turned to the diameter of the required hole and having four slots milled in it for chip clearance. The end is turned to a 90-deg. point and backed off for clearance, as shown, which gives a sharp cutting edge. It is unnecessary to back off the sides of the drill or extend the slot further up the body, as all the cutting is done at a very narrow portion of the outside of the beveled end. The chips fall toward the point of the drill and out of the flutes into the cored hole.

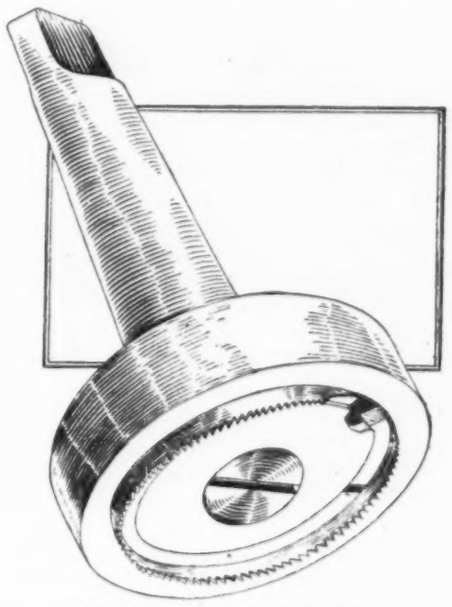
Cutting Holes and Disks with Broken Hacksaw Blades

By Herbert Fox

If you have to cut out a number of disks from almost any material that is likely to be found in the machine shop, or if you want to make holes in a piece of sheet metal, fiber or similar material, a tool like that shown in the cut makes a practical method if the diameter is not too small.

A holder is made of cast iron or machinery steel, as may be most convenient, the shank being made to go in the chuck of a drilling machine or lathe. The body is recessed to a depth of about $\frac{1}{4}$ in. to a diameter equal to that of the required disk plus twice the width of the kerf cut by an ordinary hacksaw blade.

The clamping arrangement consists of a ring, similar to a piston ring except that it is bored taper instead of parallel, with a bevel of about 15 or 20 deg., and a disk whose edge is beveled to correspond to the ring. A countersunk head screw in the center draws the disk toward the body of the tool, its movement of course



CIRCULAR SAWING TOOL

expanding the split ring, the outside diameter of which equals the inside diameter of the recess less twice the thickness of a hacksaw blade.

A blade that is flexible enough to conform to the circle (some blades are much more amenable to this treatment than others) is set into the annular groove between the body of the tool and the split ring and clamped by tightening the central screw.

Instead of using new blades for this tool, sections of blades that have been accidentally broken before becoming dull may be used. To make the tool cover a range of sizes, make adapter rings (with parallel bore) to go outside the saw blade and new clamping rings and disks for the inside.

This tool is not intended to be a manufacturing proposition, but as a "kink" to help the emergency man out of what is sometimes an awkward job.

Graphic Method of Determining Tooth Pressures of Gears

By George W. Cronk

A chart for quickly getting the tooth pressure on any spur gear is shown in the cut herewith. My position requires that I find the tooth pressure quite often, and not being able to find any chart for this purpose, I made up this one which is based on the well-known principle of logs. The three things necessary to work it are the pitch diameter, revolutions per minute and horsepower. It is not necessary to know the face of the gear.

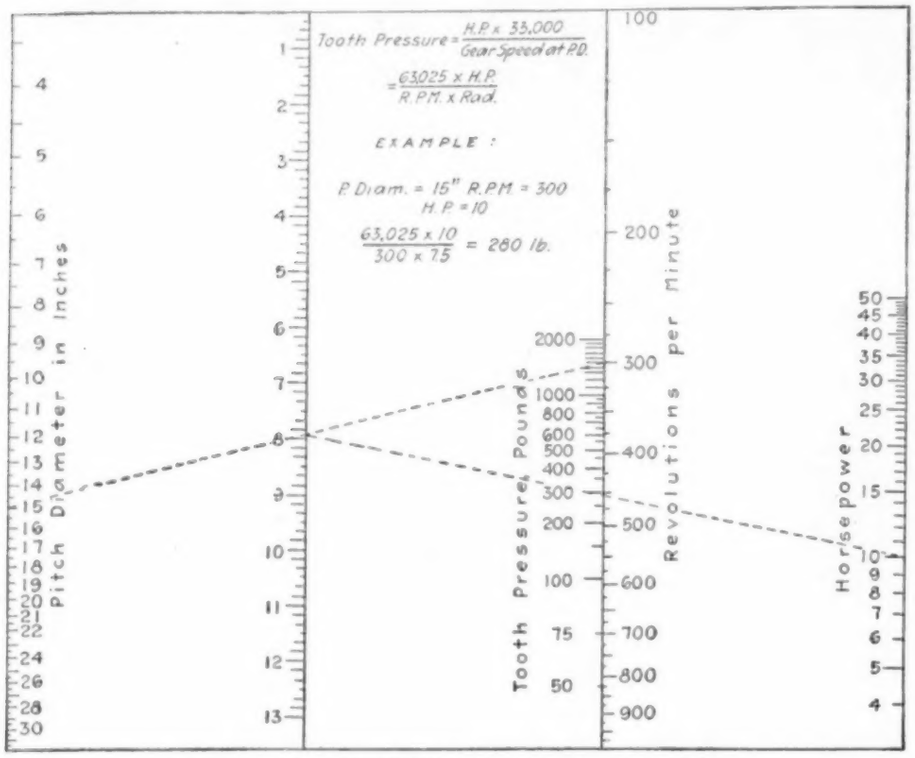

Tooth Pressure = H.P. x 33,000 / Gear Speed at P.D.
= 63025 x H.P. / R.P.M. x Rad.
EXAMPLE :
P. Diam. = 15" R.P.M. = 300
H.P. = 10
63,025 x 10 / 300 x 7.5 = 280 lb.
Pitch Diameter in Inches
Tooth Pressure, Pounds
Revolutions per Minute
Horsepower

CHART FOR DETERMINING TOOTH PRESSURES

This chart works on the principle of multiplying and subtracting with logs, and is just as accurate as a slide rule.

To work the chart, lay one end of a scale on the pitch-diameter line and swing the other end to the revolutions-per-minute line. Mark where the scale crosses the axis and from this point run the scale to the horsepower line and read the answer where the scale crosses the tooth-pressure line. Note the dotted lines on chart which show an example worked out.

This chart also holds good for pulleys if the answer is multiplied by three, to allow for the belt tension.

Internal Lapping and Laps

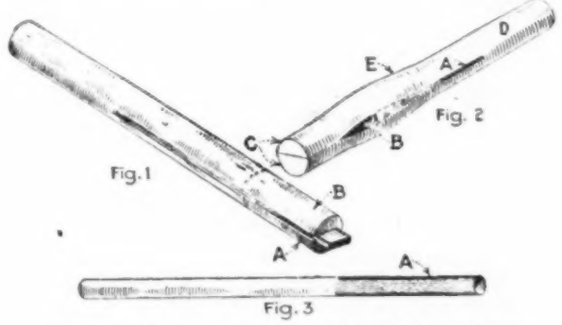
By Hugo F. Pusep

A considerable item of expense in every jobbing tool shop is the internal lap. So many different sizes of holes require lapping that often the time spent on making new laps for every job or turning down worn ones to smaller sizes, consumes more time than the actual operation of lapping.

The conventional type of lap—a split cylindrical brass or cast-iron bushing driven on a tapered arbor—is so well known that its construction will not be discussed here. It might be said, however, that where the volume of work warrants it, a set of these laps, running in sizes from ¼ in. to 1 in. by sixty-fourths, should be made and kept in good condition, always to be available when wanted; the size of the lap should be stamped on its end. When a lap of a certain size becomes worn beyond its limit of adjustment, it can be turned down $\frac{1}{64}$ in. smaller and then re-stamped. When a special size lap has been made, it is also stamped and turned into the tool supply room immediately upon completion of the job. If this method is followed, it will be found that the expense of lapping decreases in proportion to the number of laps, in good condition, in the tool supply room. There is no reason why a lap should not receive the same treatment that a twist drill, reamer or any other tool is accorded. This is to say, it should be given out to the workman on a check, and all new ones added to the total supply of laps already at hand.

It is not so much the cost of making a lap for a given job that makes the lapping expensive, but the fact that most of the laps made in the average shop are kept by the individual workmen who made them, after they get through with their job. Very often one sees a toolmaker going from bench to bench inquiring if any of his fellow workmen has a lap of a certain size. After he has made the rounds of all the shop, he sets to work and makes the lap, notwithstanding the fact that Joe had in his tool box the very size of a lap that John was looking for. The only reason why Joe wouldn't lend the lap was that he thought it was a mighty good lap and would soon become undersized if the whole shop were to use it, and besides, John wasn't his particular friend anyway. The foregoing is not an exaggeration, but will be corroborated by all readers who are familiar with conditions in an average tool shop.

Besides the split-bushing form of internal lap, there



FIGS. 1 TO 3. LAPS FOR INTERNAL WORK

are several other forms of laps which, if properly used, will give very satisfactory results. The split rod with emery cloth wound around its end, will often save much time in rough-lapping bushings with holes from $\frac{3}{4}$ in. to 1 in. in diameter, the last few tenths, of course, being removed with a more accurate lap.

Another form of lap quite frequently used, is the split rod with wedge adjustment at the end, as shown in Fig. 1. If it is left parallel for the entire length, the corner at *A* will do all the lapping and a poor job will be the result. When the corner is filed off in a long bevel as shown by dotted lines at *B*, it will do better work, but a tendency to bell-mouth the hole will always be present with this lap.

FIG. 4. ROUGHING A SMALL LAP WITH A FILE

Fig. 2 shows a lap which is very easily made and is a wonder for efficiency. This lap can be used for all sizes of holes from $\frac{3}{16}$ in. to about $\frac{3}{4}$ in. in diameter. A piece of cold-rolled steel is held in the collet of the bench lathe and turned to a slip fit for the bushing or dowel-pin hole which is to be lapped. It is then split about two-thirds of its length as shown at *A*, Fig. 2, using a jeweler's hacksaw for the smaller sizes. A screwdriver, or any similar object is forced into this saw-cut at *B* and the free ends *C* of the split rod are pressed together in a vise. When the screwdriver is pulled out, this lap is ready for use.

The principle upon which this lap works is very simple. A lapping compound is put into the opening *B* and while the lap rotates at high speed, held by the solid end *D* in the collet or the drill chuck, the hole that is being lapped forces the two halves *E* together, thereby causing the lapping compound to squeeze out as the bushing is worked back and forth. This lap works very rapidly because the springing tendency at points *E* will keep the lap in contact with the walls of the hole at the right pressure necessary to remove the metal without danger of the lap seizing in the hole. Cold-rolled steel is the best material to use for this lap, although drill rod can also be used. A lap like this can be made in 15 or 20 min.; it will not cause bell-mouthing if used with common care, and will last a long time.

Fig. 3 shows another form of lap suitable for small holes. It is also made of cold-rolled steel. The working end of this lap consists of a plain rod turned to a slip fit for the hole to be lapped. A hand knurling attachment is used to expand the end of the rod, as at *A*, till it is a tight-working fit in the hole to be lapped. A lapping compound smeared in the knurl marks supplies the abrasive action of the lap. After it wears loose, the abrasive is washed off with gasoline, and the knurling attachment is again run over the end to bring it to the correct diameter. The action of this is slow as compared to the one previously described, but where the hole is too small for a split lap to be used, the knurled lap will answer the purpose. An attachment with parallel knurls is the best one to use, but where that is not obtainable, cross knurling will do.

For very small internal laps, where knurling is out of the question, the lap shown in Fig. 4 can be used. A short piece of drill rod *A* is selected that will just enter the hole to be lapped. While it is revolving in the bench lathe at high speed, a smooth piece of steel is held below and just touching it, as at *B*. Now with a smooth edge of a file or any other narrow, hardened-steel object *C*, a succession of light, rapid taps is given the revolving rod—working back and forth over a length equal to more than the length of the hole to be lapped—the rod being supported by the flat-steel piece *B*. This causes a series of minute burrs to be raised on the rod, expanding it sufficiently to act as a lap. An experienced toolmaker can produce a hole with this lap, that is perfectly smooth and straight. Drill rod is the best material to use for this form of lap, because its stiffness eliminates the possibility of a curved hole.

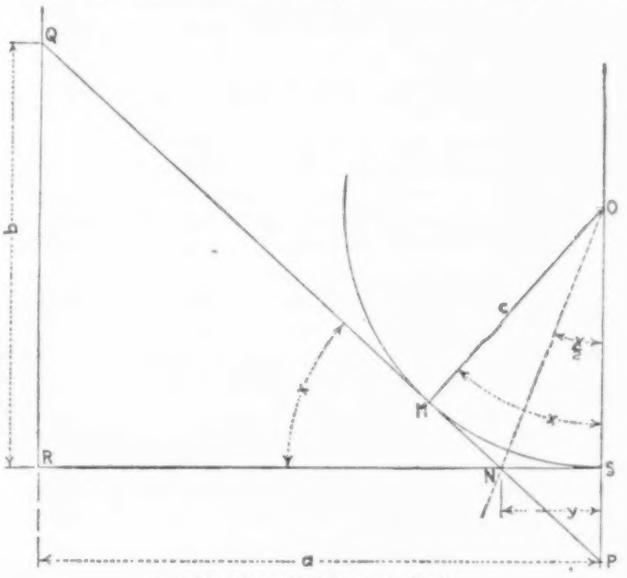
A Little Question of Trigonometry

In the accompanying sketch the radius *C* of the circle and the distances *B* and *A* are known. How would you find the angle *X* when the hypothenuse of the triangle is tangent to the circle? Please answer through the columns of the *American Machinist*.

F. A. McCURDY.

A SOLUTION

To make the solution a general one, I have designated the distance from the apex of the triangle to the



A TRIGONOMETRY PROBLEM

center line of the circle by letter y and substituted letters for the known values.

Triangles *MOP* and *NQR* are similar because their sides are respectively perpendicular. Consequently, the angle *MON* is equal to the angle *QNR*, or X. From geometry we know that the line connecting the center of a circle with the intersection of two tangents to the circle bisects the angle subtended by the radii to the points of tangency. Therefore, the angle $NOS = \frac{X}{2}$.

From the known values we can obtain the following trigonometric relations:

$$\text{From triangle } NRQ, \tan X = \frac{b}{a - y} \qquad (1)$$

$$\text{From triangle } NOS, \tan \frac{X}{2} = \frac{y}{c} \qquad (2)$$

To eliminate the unknown distance y we put (1) and (2) in the forms:

$y = a - \frac{b}{\tan X}$ and $y = c \tan \frac{X}{2}$ and equate the two:

$$a - \frac{b}{\tan X} = c \tan \frac{X}{2}$$

$$\text{Then } a - \frac{b \cos X}{\sin X} = \frac{c\,(1 - \cos X)}{\sin X}$$

$$a \sin X = c - c \cos X + b \cos X$$

$$a^2 \sin^2 X = c^2 - 2c(b - c) \cos X + (b - c)^2 \cos^2 X$$

Since $\sin^2 X = 1 - \cos^2 X$, we can say:

$$a^2 - a^2 \cos^2 X = c^2 - 2c(b - c) \cos X + (b - c)^2 \cos^2 X$$

$$[a^2 + (b - c)^2] \cos^2 X + 2c(b - c) \cos X + (c^2 - a^2) = 0$$

$$\cos^2 X + \frac{2c\,(b - c) \cos X}{a^2 + (b - c)^2} = \frac{a^2 - c^2}{a^2 + (b - c)^2}$$

Completing the square of this equation gives:

$$\cos^2 X + \frac{2c\,(b - c) \cos X}{a^2 + (b - c(^2} + \frac{c^2\,(b - c)^2}{[a^2 + (b - c)^2]^2} = \frac{(a^2 - c^2)}{a^2 + (b - c)^2} + \frac{c^2\,(b - c)^2}{[a^2 + (b - c)^2]^2}$$

Extracting the square root of both sides we have:

$$\cos X + \frac{c\,(b - c)}{a^2 + (b - c)^2} = \sqrt{\frac{(a^2 - c^2)\,[a^2 + (b - c)^2] + c^2\,(b - c)^2}{[a^2 + (b - c)^2]^2}}$$

This expression can be simplified to the form:

$$\cos X = \frac{-c\,(b - c) + a\sqrt{a^2 - 2bc + b^2}}{a^2 + (b - c)^2}$$

This gives a general equation from which the cosine of the unknown angle X and the angle itself may be obtained, no matter what the relation between the various quantities.

In the particular case given, $a = 11.75$, $b = 5.6875$, $c = 3.6875$. Making the substitutions:

$$\cos X = \frac{-3.6875\,(5.6875 - 3.6875)}{(11.75)^2 + (5.6875 - 3.6875)^2} + \frac{11.75\sqrt{(11.75)^2 - 2 \times 5.6875 \times 3.6875 + (5.6875)^2}}{(11.75)^2 + (5.6875 - 3.6875)^2}$$

Solving this by the use of logarithms gives us:

$$\cos X = 0.88554$$

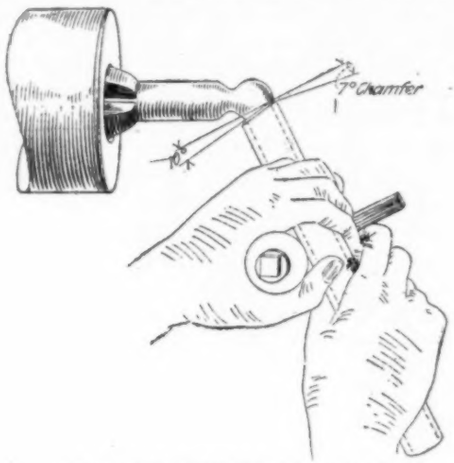
$$X = 27^\circ\ 41'$$

K. H. CONDIT,
Associate Editor.

Turning a Ball on the End of a Rod

BY JULIUS REICH

A quick and handy way to turn a ball on the end of a rod, as for instance in making ball handles for machine tools, is to take a pipe the inside diameter of which is somewhat less than that of the desired ball and grind it as shown in the sketch, leaving a



TOOL FOR PRODUCING A BALL

keen edge. Cyanide hardening completes the tool.

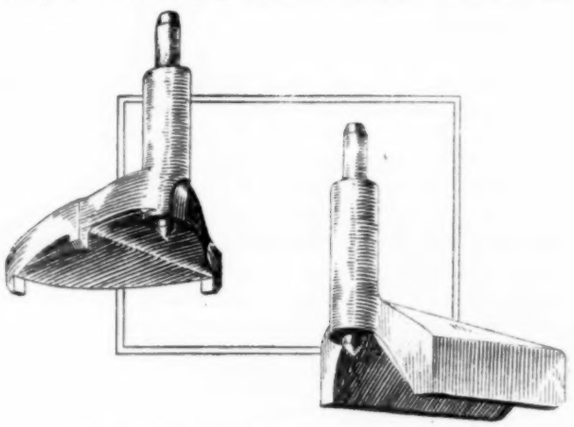
Put a tool shank in the toolpost for a rest and use the pipe as a hand tool, giving it a twisting motion which can be made to cut a smooth shaving from the ball.

Before using the tool, the ball should be brought approximately to shape, and the hand tool used only for finishing cuts.

Precision Prick-Punches

BY J. A. LUCAS

Two tools that will be found quite handy by every toolmaker who does any amount of laying out are shown in the sketch. For accurate work it is necessary that a prick-punch be nicely ground on the point and that when



PRICK-PUNCHES FOR ACCURATE WORK

used it be held exactly perpendicular to the surface being laid out. The construction of these tools is so obvious that they need no description. The advantage that they possess over the ordinary form wherein the punch is fitted to the central hole in a bushing or a V-block is that the point is always in plain view of the user.

Insufficiency of Fire Escapes

By CHESLA C. SHERLOCK

THE obligation to provide fire escapes on buildings where there were large numbers of persons at work was unknown at common law. The landlord owed no duty of protection to his tenants in this respect and if they took the premises without adequate protection, the landlord was generally held blameless.

The statutory law, however, as it exists today, does not adopt or sanction any such loose regard of the rights of others. It imposes an obligation upon every owner of a building to make that building reasonably safe and to provide some means of escape for the inmates in case of the fire hazard.

The question naturally involves some new principles arising between landlord and tenant, and between the landlord and the employees of the tenant or sub-tenant. As to the respective rights and liabilities there is a difference of opinion in many jurisdictions which can be noted only by a study of the leading cases upon the subject from the more important courts.

In a New Jersey case it was contended that if a tenant took a building without making an examination as to the sufficiency of the fire escapes, that this relieved the landlord and that the tenant was responsible. But the court did not stoop to this narrow view. It held that the tenant owes no duty to the landlord to make any examination of the building to see that the fire escapes are in compliance with the statute, but that he has a right to assume that the landlord has performed the duty imposed upon him by statute. The court further held that even though the tenant discovers that the landlord has failed to perform his statutory duty, he may reasonably assume that the landlord will perform that duty at any time, and not continue to disregard the law. This same principle was also approved by a Nebraska court.

This simply means that the statutory obligation imposed by the law looks entirely to the landlord for compliance and that it operates only upon him. To the tenant it has no application except in special instances, and the tenant need not concern himself with carrying out its provisions unless he must do so as a matter of protection to himself, but in this respect his action is voluntary and not mandatory as it is in the case of the landlord. It was also held in the same case that the mere length of the occupancy of the building, unaccompanied by some affirmative act or circumstance on the part of the tenant showing an intent to relieve the landlord from the consequences that might result to the tenant from the landlord's failure to perform the statutory duty imposed upon him of erecting fire escapes, cannot relieve the landlord from responding in damages in case a fire breaks out and the tenant suffers injury by reason of the absence of fire escapes.

In these relations there is no such thing as an assumption of risk by the tenant of the landlord's failure to provide fire escapes, as this duty has no relation whatever to the common law.

It was held in a Missouri case that the occupants of a building do not, even by long-continued usage, assume the risk of danger from the owner's neglect to comply with the statutes requiring the provision of fire escapes at least where the building is in the possession of and operated by a tenant. In the same case it was held that the jury must determine whether or not the modes of exit claimed as equivalent to fire escapes required by statute constitute a substantial compliance with the statute where a literal compliance is plainly absent.

In this respect it might be well to note that where the question of compliance to a statutory duty is at bar, if the person charged with the violation of such statutory duty can show a substantial compliance to the statute even though he cannot show a literal compliance, he will generally be excused from the penalties imposed for a neglect of such duty. The law is not strict except in criminal matters. It does not require a literal compliance in its mandates although it expects such compliance.

In a Minnesota case it was held that there can be no doubt that if a landlord owes a duty to a tenant in the manner of providing fire escapes, the same duty is also owing to the members of the family, the servants or workmen of the tenant.

In this case it was shown that the statute required one noncombustible ladder or stairway for each 20 persons or fraction thereof that the building accommodated above the first story, but did not state how far down the ladder should extend, and it was held a question for the jury to determine whether there was negligence on the part of the landlord in not bringing the ladder down closer to the ground than 20 ft. so as to afford a reasonably safe escape from the building.

In a Kentucky case it was held that the ordinance of the City of Louisville requiring fire escapes on tenements and factory buildings is mandatory, and its violation by a landlord in failing to provide fire escapes, being the proximate cause of the injury or death of occupants, is actionable negligence. It was also held that the fact that the building was erected before the enactment of the ordinance does not relieve the landlord from liability for failure to comply with its provisions, since it applies to buildings erected before as well as after its enactment. It also appeared in this case that the landlord had used a lease which contained a provision relieving him of liability for failure to keep his building in repair, but it was held that this did not relieve him from liability for injury or death of occupants for a failure to provide the fire escapes necessary for safety as required by the ordinance, or to keep in reasonably safe condition for use in case of fire, a ladder and bulkhead door for escape to the roof as required by statute.

In a New York case it was held that an employer who fails to equip his building with fire escapes as required by statute is liable for the death of an employee due to such failure, regardless of the question of his negligence in other respects. In this case a three-story shed connected with a tannery and used for dyeing hides, in which employees worked, is within the operation of the statute requiring fire escapes on factories and providing that such term shall be construed to include any mill, workshop or other manufacturing or business establishment where one or more persons are employed at labor.

In an Illinois case it was held that the failure of the owner, or of a lessee in full possession and actual control under a lease for years, of a business building,

to obey a statute requiring such buildings to be furnished with suitable, sufficient and proper fire escapes of metal reaching from the top floor to or nearly to the ground, gives rise to a cause of action for negligence in favor of one lawfully in the building when a fire breaks out and injured because of such inadequate means of escape.

It will be noted here that the landlord's or tenant's obligation, where the tenancy is for years, is extended not only to employees of the one in possession of the building but also to all who are lawfully on the premises when the fire breaks out. This simply means that the liability extends to everyone, practically without exception, and that the fire-escape protection established by statute is to extend to the general public and not to certain persons or classes of persons.

In an Indiana case it was held that the failure of an owner of a three-story building used for a factory shop on the third story, to equip it with fire escapes pursuant to a mandatory statute for the protection of workmen employed therein, must be deemed to be the proximate cause of an injury sustained by workmen in jumping from a window during a fire, where no other means of escape existed.

In Pennsylvania it was held that the duty of the owner of the building, in which employees or operatives are usually employed in the third or a higher story, to provide a permanent, safe, external means of escape therefrom in case of fire, independently of all internal stairways, does not end in all cases with the erection of a single fire escape, even though in the details of its construction it conforms to the requirements of the statute, for the statute also provides that the number and location of such escapes are to be governed by the size of the building and the number of its inmates and arranged in such a way as to make them reasonably accessible, safe and adequate for such purposes.

Here again we have an example of the "substantial compliance" rule. Even though there was a literal compliance in this case, by the building of one fire escape, it did not substantially comply with the statute, so the owner's liability under the statute was not entirely discharged.

It was also held that the owner of a building failing in his statutory duty to provide an adequate means of escape in case of fire cannot claim that the injuries sustained by an inmate in escaping from the building during a fire were due to want of familiarity on the part of the injured person with the means of escape that had been provided. It is not the lack of familiarity with the means of escape, but the inadequacy of the means, that is the proximate cause of the injury in such a case.

In another New York case it was held that the obligation to maintain a fire escape on a tenant factory "connected with the interior by easily accessible and unobstructed openings" was imposed upon the owner instead of "the respective lessees or tenants;" and he could not avoid liability by delegating the performance of the duty to others. It was also held that the owner was liable to employees of a subtenant, who had erected a partition cutting off, or partly so, the fire escapes.

The Illinois act not only provides for a sufficient and reasonable means of escape for employees in case of fire, by more than one means of egress, but to avoid so obstructing the means of escape that it cannot be used when a fire occurs.

In a certain case the court said: "It is undoubtedly true that there was no duty at common law to provide a fire escape. But where it is alleged that a fire escape was in fact provided by an employer for use of his employees in case of fire, we think the duty devolved upon such employer, apart from the statute, to use reasonable care to keep the means of escape thus provided reasonably free from obstructions so that it may be used as a means of escape when occasion arises. The presence of a fire escape is, in such case, an assurance of safety upon which the employee may rely to a reasonable extent, precisely as he is entitled to rely, to a reasonable extent, upon the apparent condition of any other instrumentality or place provided for his use in and about the work which he is engaged to perform."

In Illinois, Indiana and New York it has been held that the duty to provide and maintain fire escapes as required by statute is not dependent upon any notice or other action by a municipal officer, such as the fire chief, factory inspector, or the like, so that the failure of such an officer to give notice concerning the erection and maintenance of fire escapes is no excuse for the failure of the responsible person to provide them.

These statutes are mandatory in nature, as has been held by the courts again and again, and they themselves are notice to the world of their terms and conditions, and being mandatory in nature they must be complied with by the responsible person or he will be charged with the penalties or liabilities imposed for a failure to obey their provisions and perform the duties imposed.

In a Nebraska case, it was held that the violation of any statutory or valid municipal regulation established for the purpose of protecting persons or property from injury is sufficient to prove such a breach of duty as will sustain a private action for negligence, if the other elements of actionable negligence concur.

It has been generally held in a number of cases that the owner of a building who has failed to provide fire escapes on his building pursuant to a mandatory statute, is not liable under the terms of that statute unless his failure to obey the statute was the proximate cause of the death or injury of the claimant or the claimant's decedent.

But it must be kept in mind that instances where the failure to provide proper escapes is not the proximate cause of such injury or death are few and exceedingly far between because the statutes generally provide that such a failure shall be deemed the proximate cause of injuries or death, and unless there are very unusual circumstances present the courts will so hold in practically every case.

It is the purpose of the law to protect life, limb and property and to safeguard the common rights of man. And when the owner of a building fails to take heed of its mandatory requirements looking to this end, it will, in the vast majority of cases, impose its penalties upon such person.

The best criterion of the landlord's liability, or that of the employer-owner of a factory building is, of course, the state statute relating to fire escapes and protection from the fire hazard.

These statutes are more or less similar in each state, and the uniformity of the court decisions upon this question is remarkable, but no owner of a building should for a moment assume anything as to his liability. He should inform himself as to his exact liability and follow his statutes in performing the duty imposed upon him.